Energy Economics and Environment

Lecture 6

EVROPSKÁ UNIE
Evropské strukturální a investiční fondy
Operační program Výzkum, vývoj a vzdělávání

MINISTERSTVO ŠKOLSTVÍ, MLÁDEŽE A TĚLOVÝCHOVY

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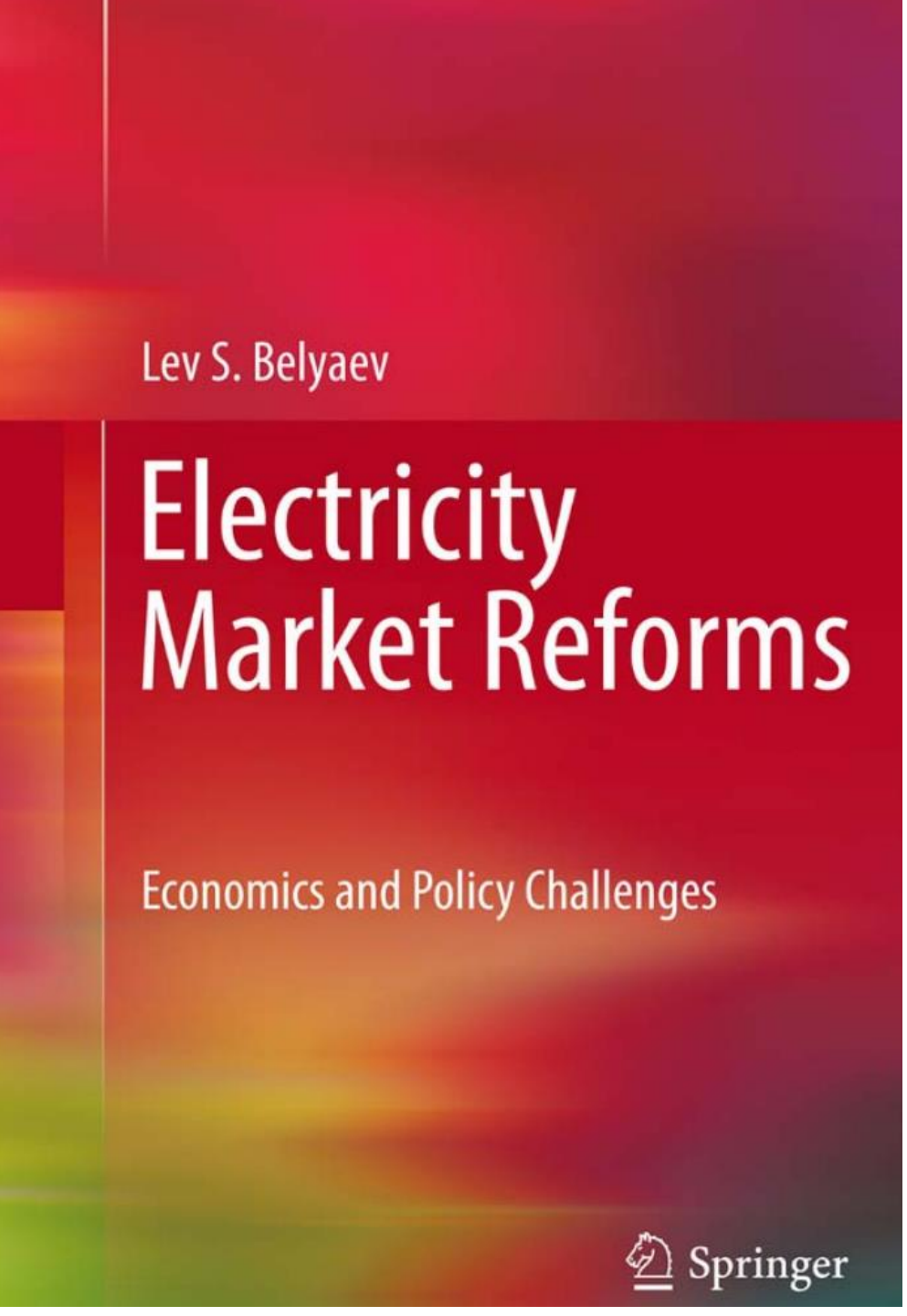
The electrical system 2

Generation (power stations)

Markets refresher



Belyaev (2011, p.225):

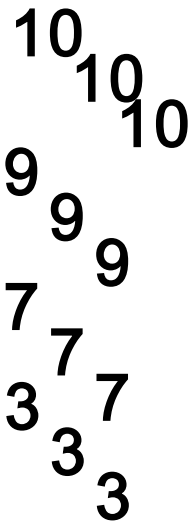
"In the short run, the relationships between average variable and the total costs of power plants and the annual electricity output do not have an U-shaped form (with minimum)."

"Thus, power plants should participate in the competitive wholesale market **with their total (but not marginal**, as it is accepted in the theory of microeconomics) costs not to be a bankrupt."

Belyaev (2011) Electricity Market Reforms: Economics and Policy Challenges. Springer

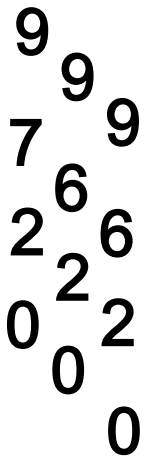
Consumer:

Maximum buying price

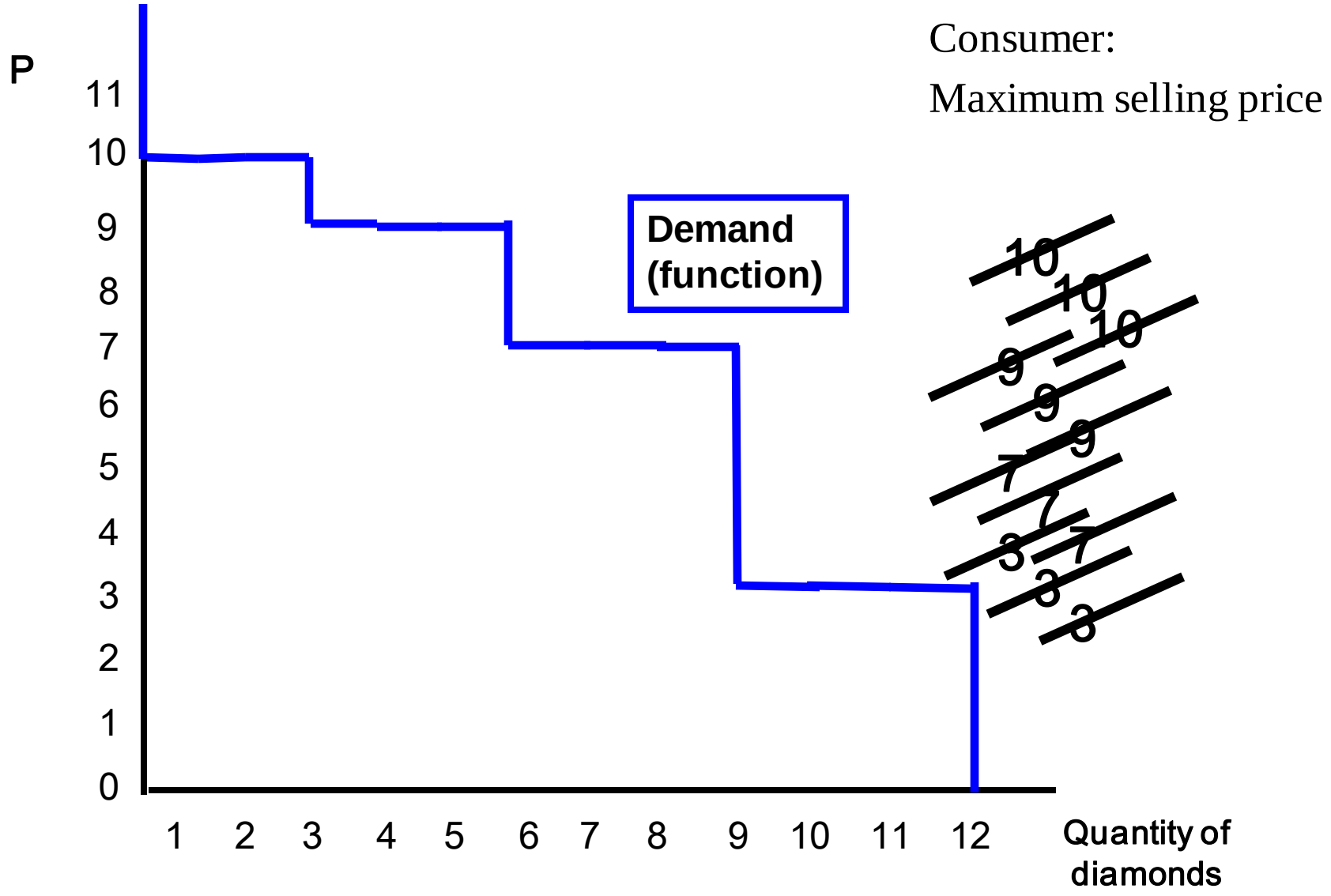


Producer:

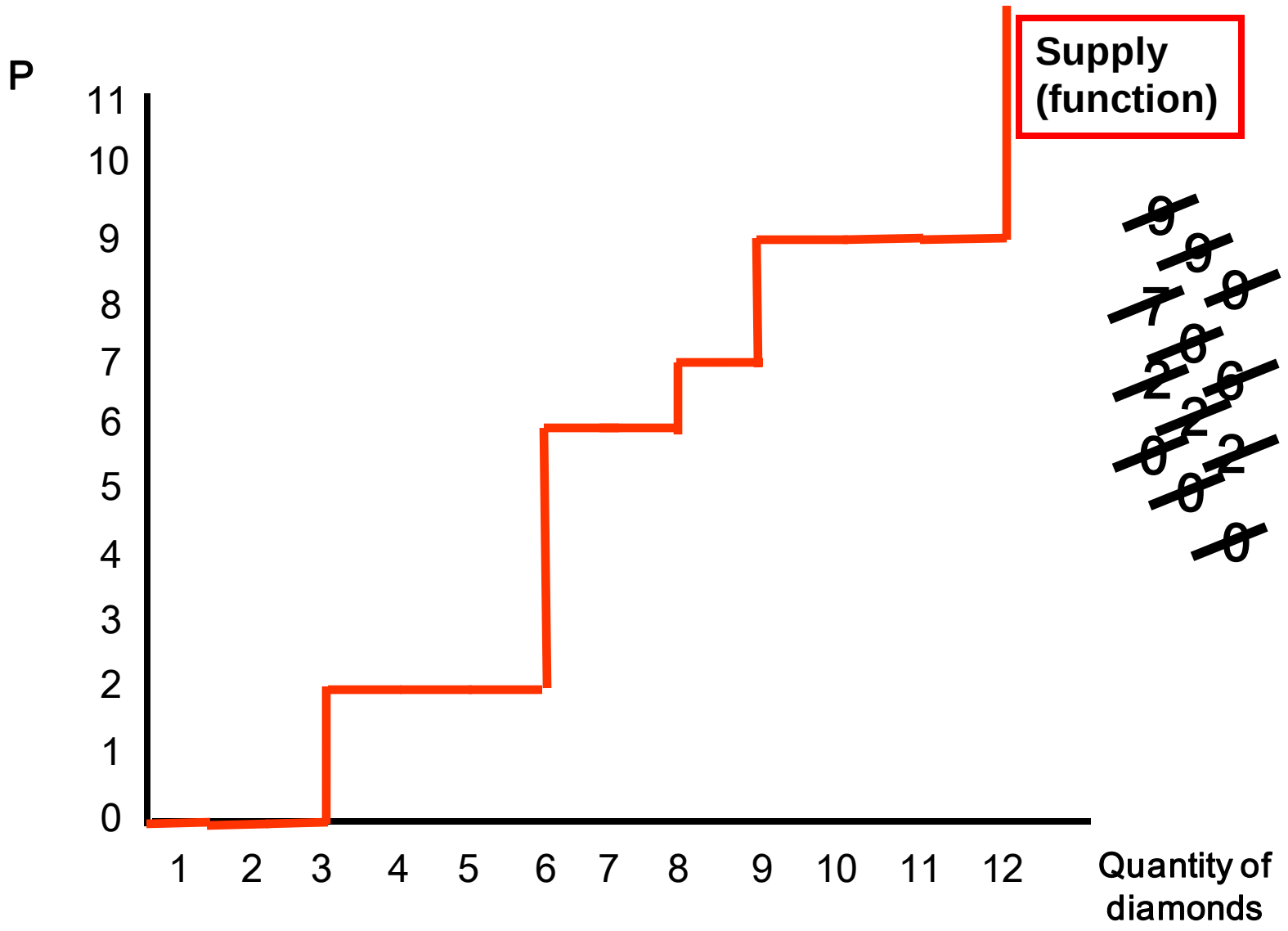
Minimal selling price



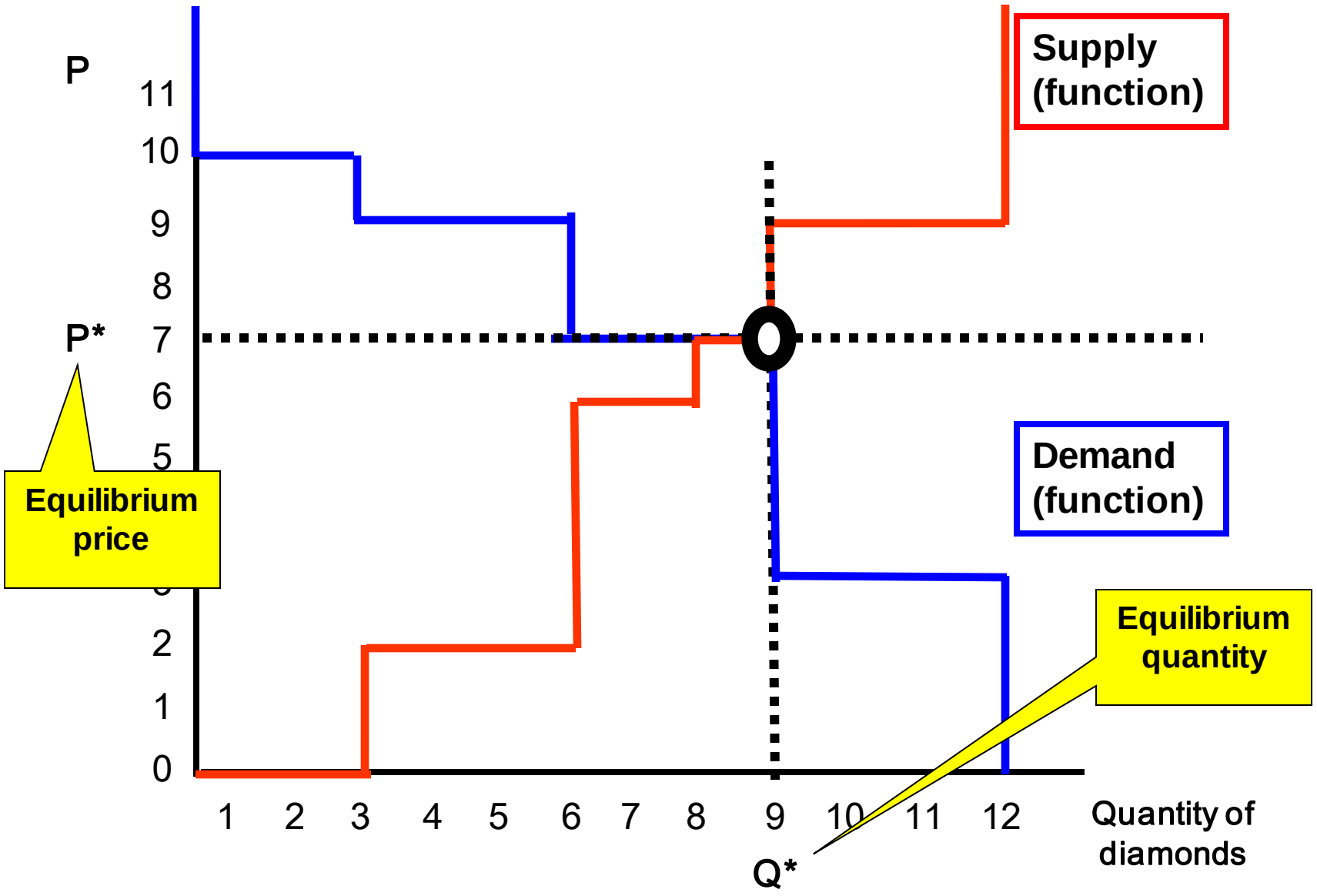
Deriving a the equilibrium price



Deriving a the equilibrium price

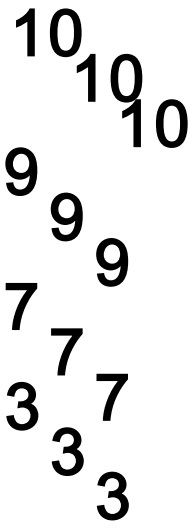


Deriving a the equilibrium price



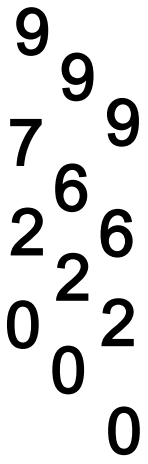
Consumer:

Maximum buying price



Producer:

Minimal selling price



Free market mechanism imposes a rich structure

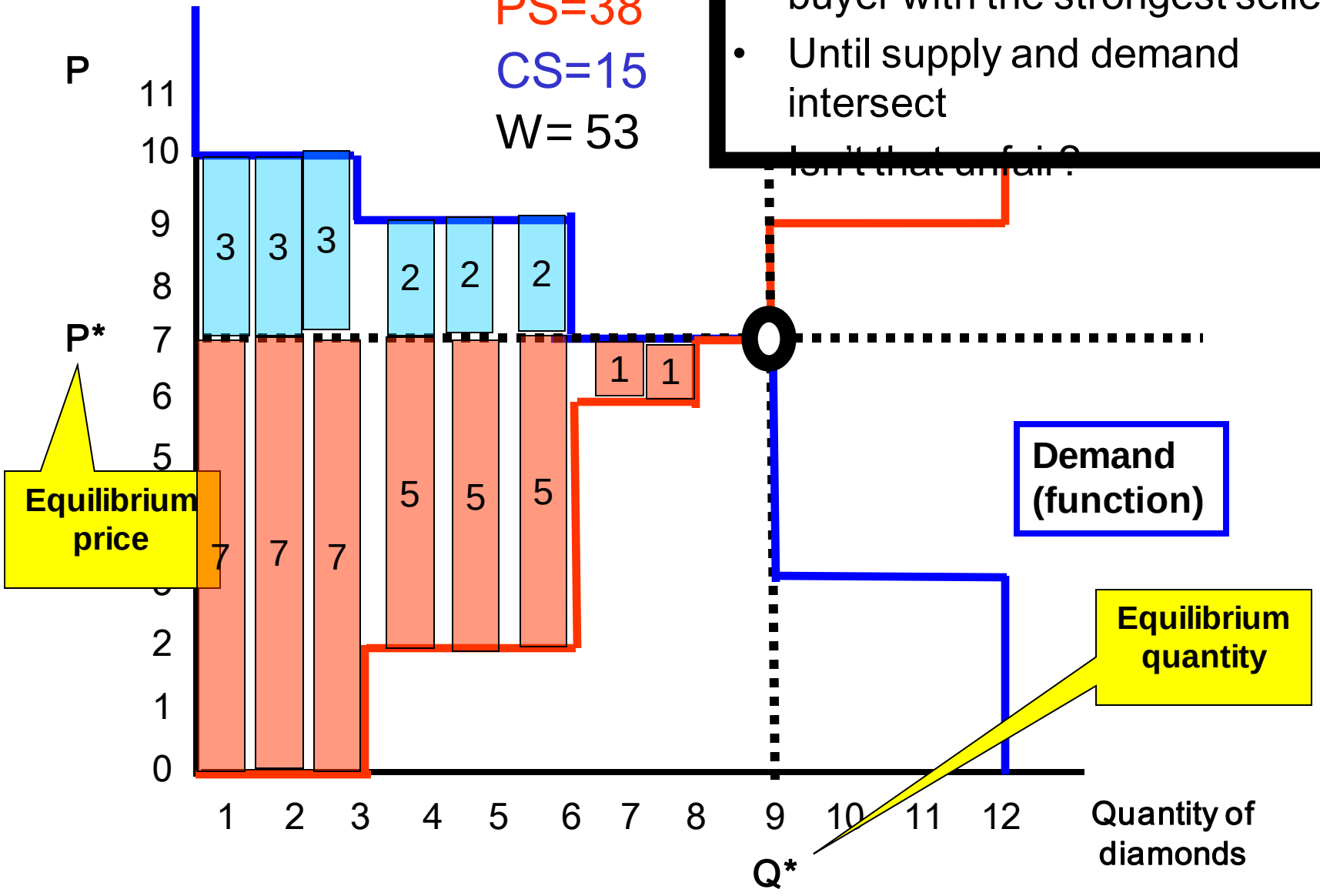
Looking at t

- You always pair the strongest buyer with the strongest seller.
- Until supply and demand intersect
- Isn't that unfair?

PS=38

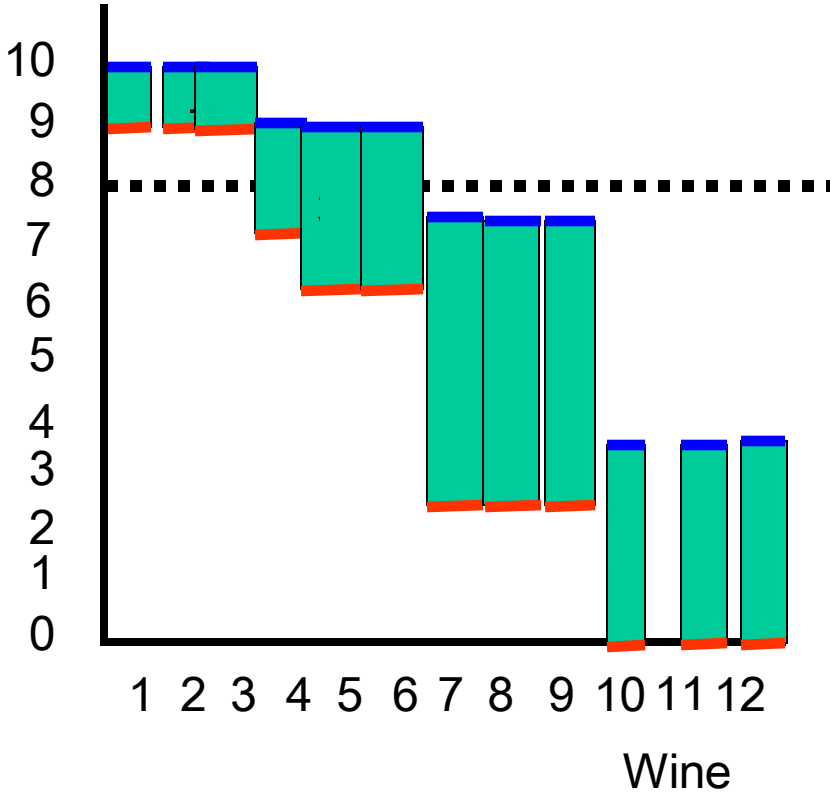
CS=15

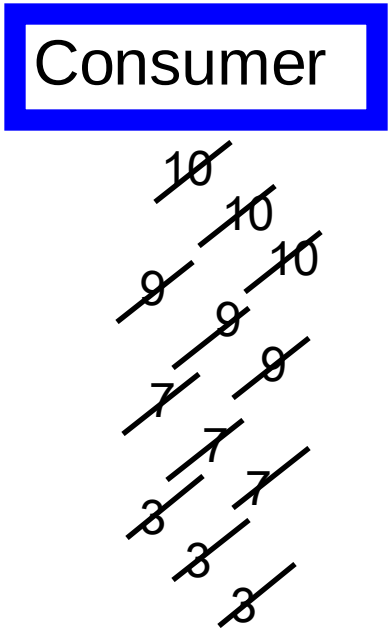
W= 53

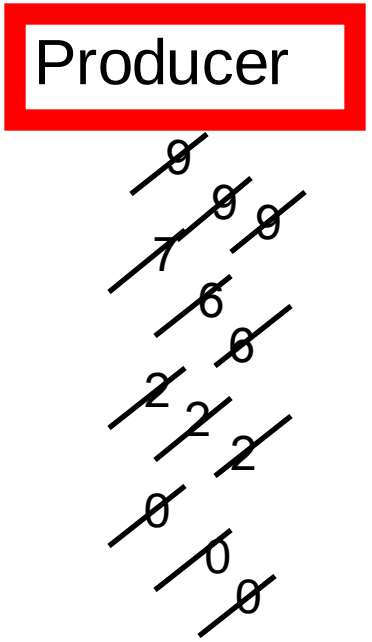


Other possible arrangements: Communist *"fair"* dictator

Could this be more efficient?



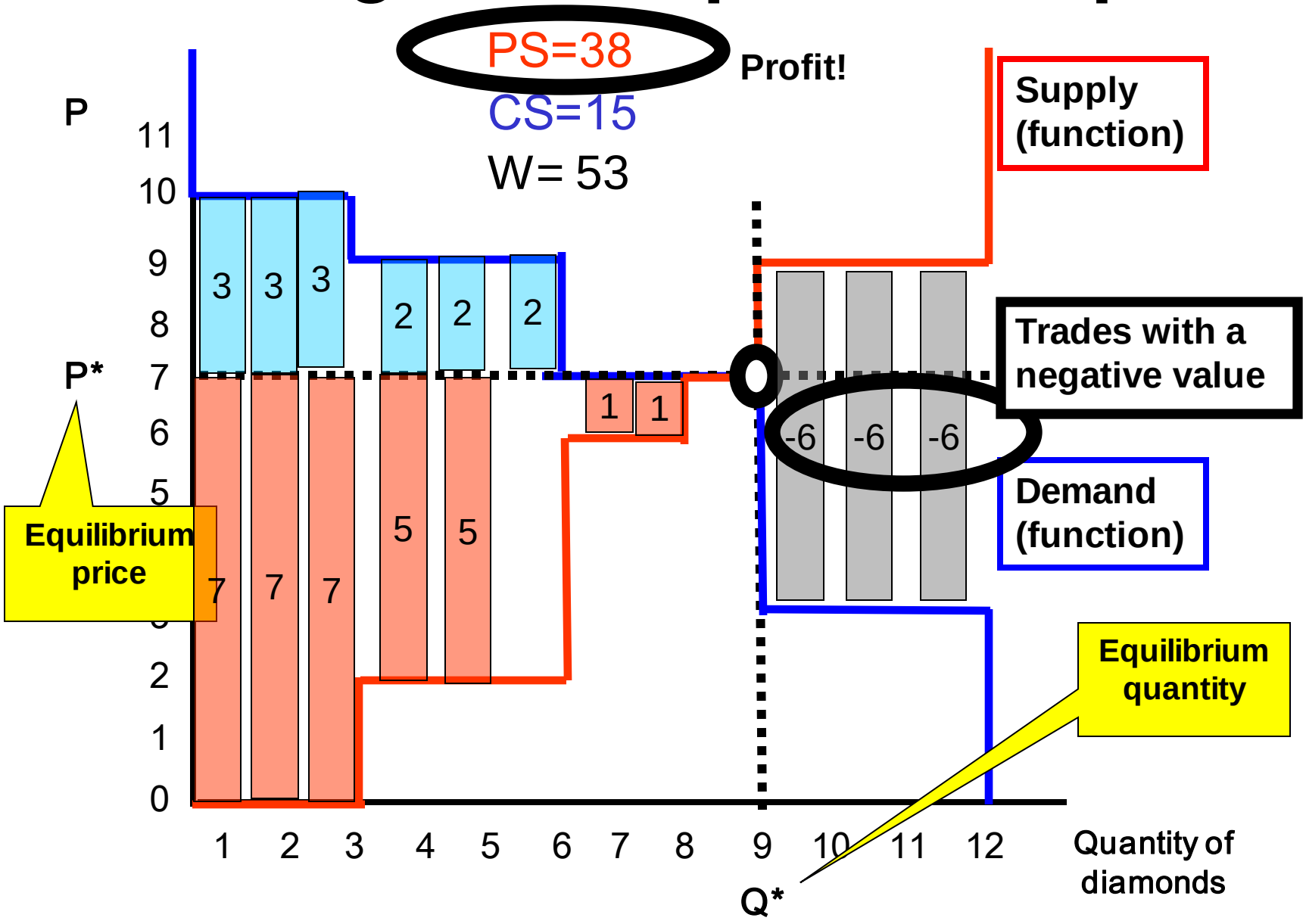




W= 35
W(Free market)=53
(difference =18)

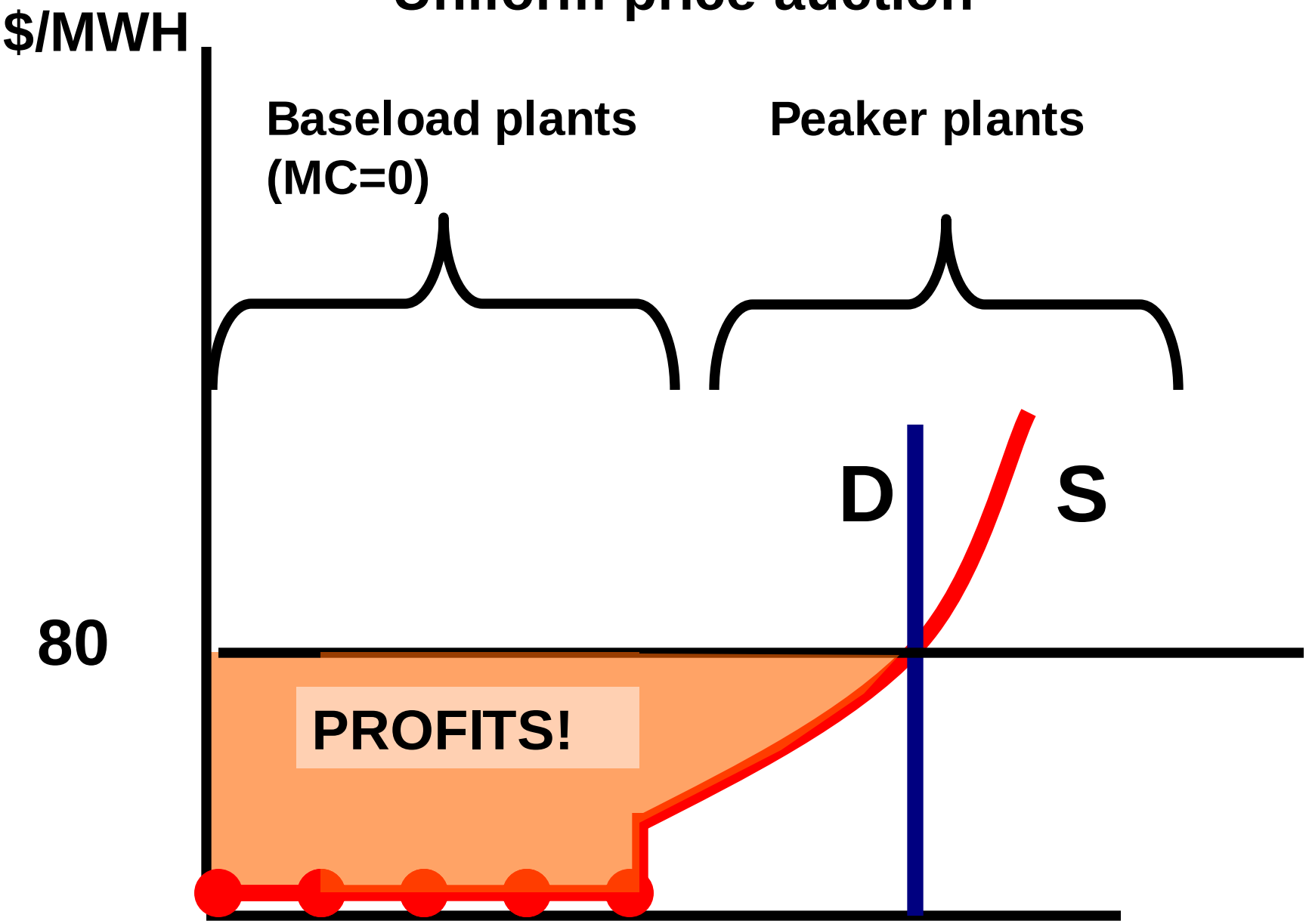
Free market maximizes W=CS+PS

Deriving a the equilibrium price

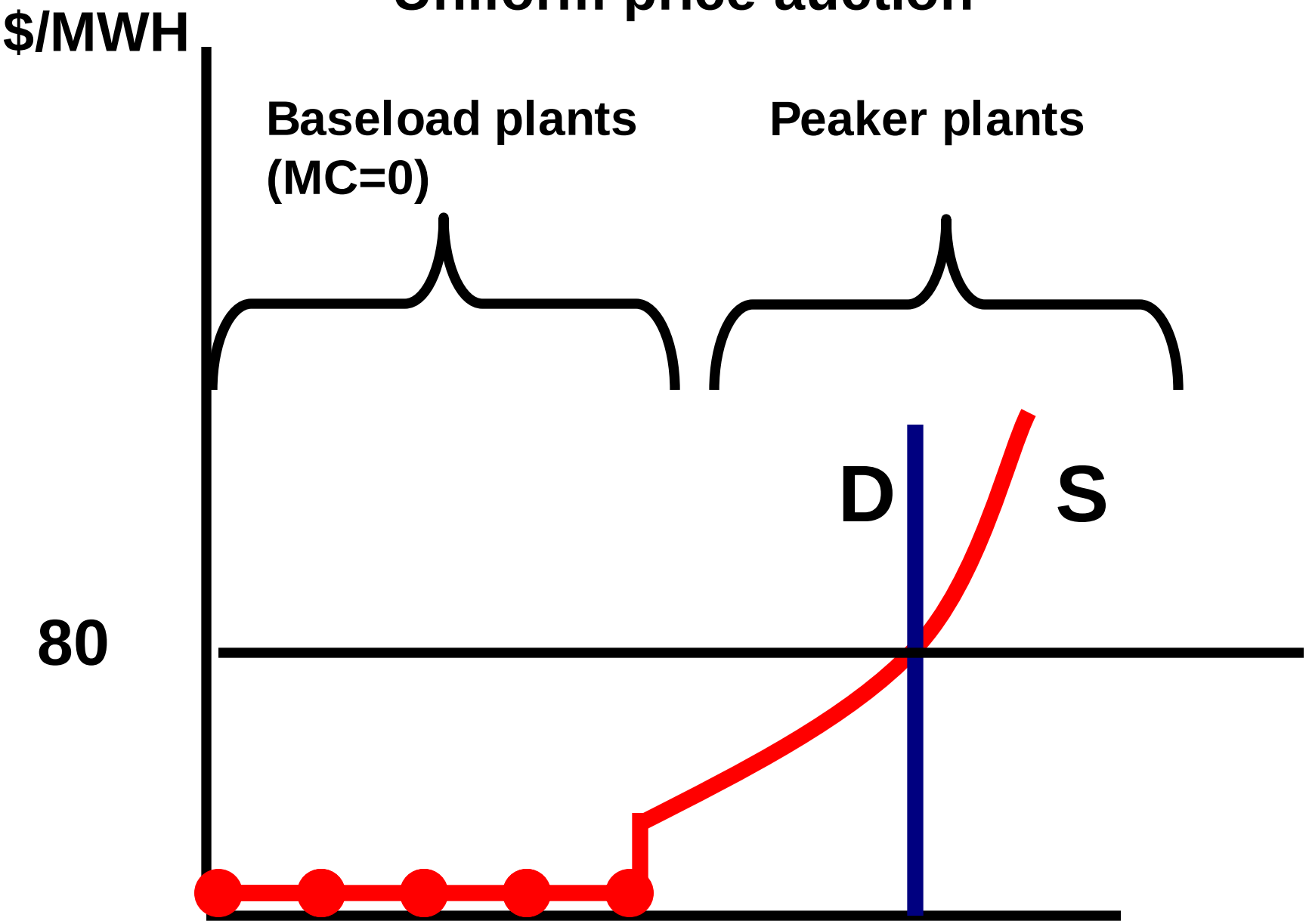


Prices in purely competitive markets (energy- only markets)

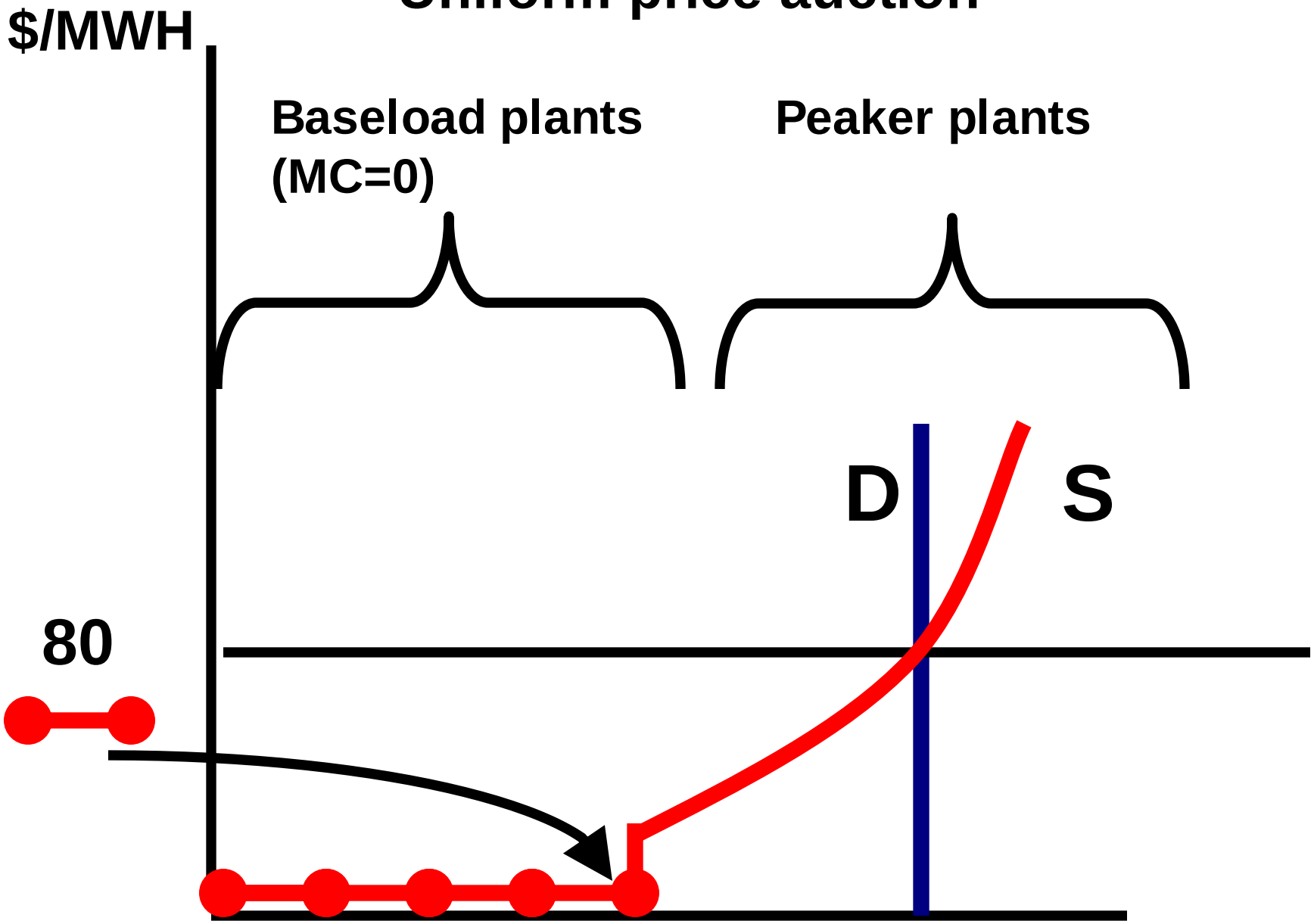
Uniform price auction



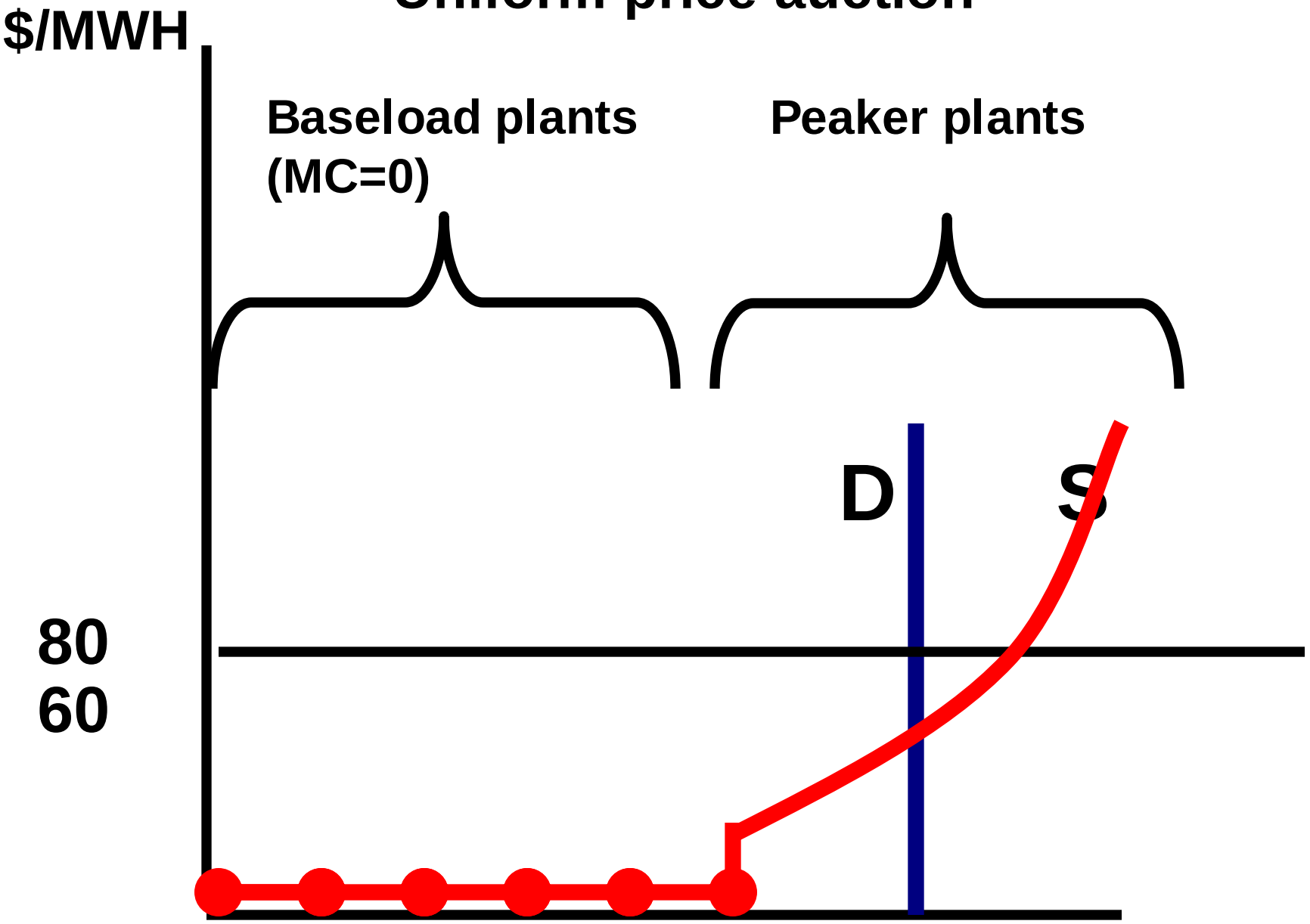
Uniform price auction



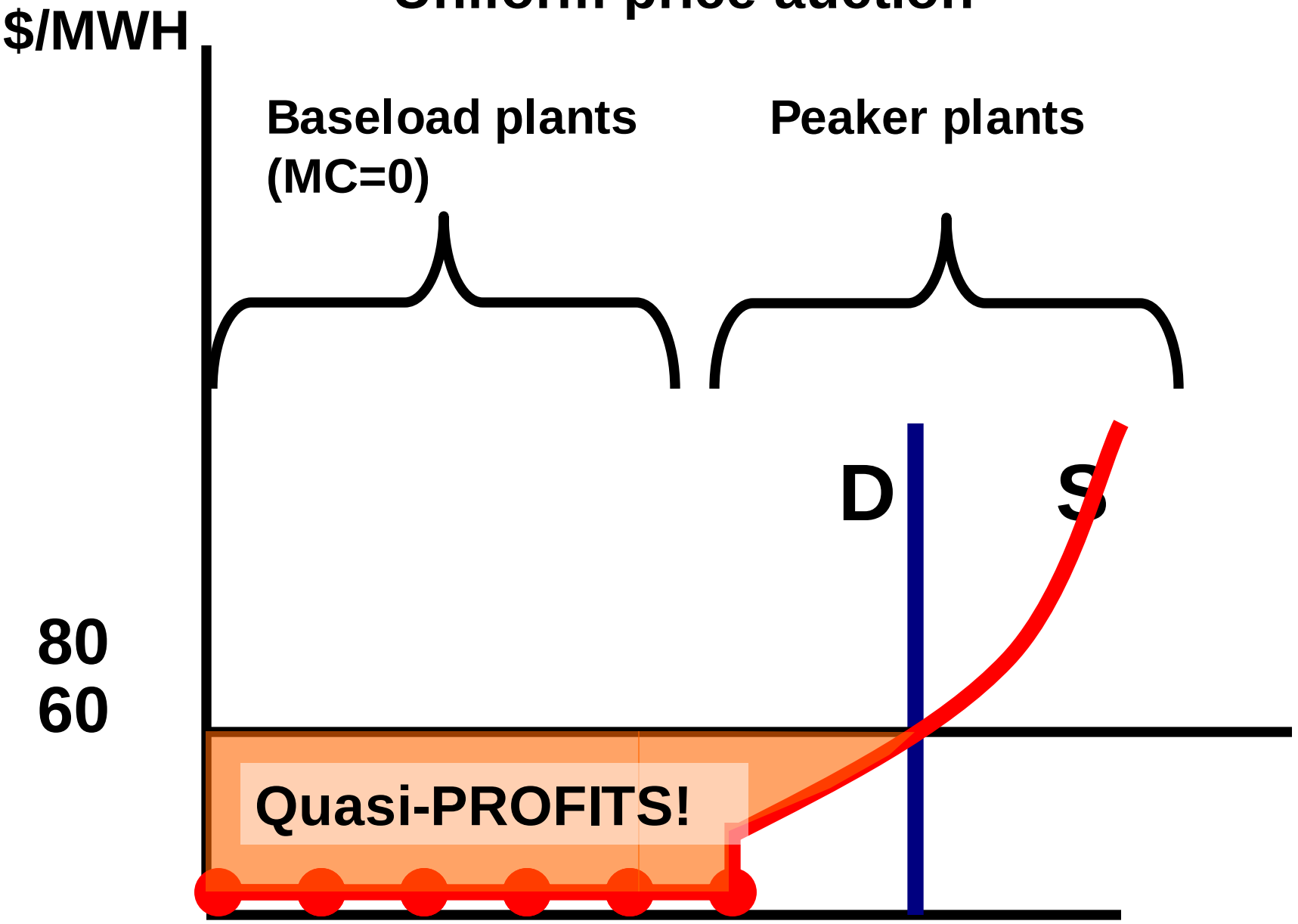
Uniform price auction



Uniform price auction



Uniform price auction



Peak-load pricing

$$L[\vec{Q}_S, K, \vec{\mu}_S] = \sum_s \alpha_S \cdot \left(U_S[Q_S] - cQ_S\right) - f \cdot K + \sum_s \alpha_S \cdot \mu_S (K - Q_S)$$

Q_S : $U_S'[Q_S] = c + \mu_S$ — $\#S$ equations

K : $f = \sum_s \alpha_S \mu_S$ — 1 equation

μ_S : $\mu_S (K - Q_S) = 0, \mu_S \geq 0, (K - Q_S) \geq 0$ — $\#S$ equations

If using up to capacity $Q_S = K$

Then $\mu \geq 0$ $\Rightarrow U_S'[Q_S] = c + \mu_S \geq c$

If using less than capacity $Q_S < K$

Then $\mu = 0$ $\Rightarrow U_S'[Q_S] = c$

The fixed costs are recovered by the charges μ

Thus only the ones that use the full capacity contribute to cost-recovery!

Is this what is applied?

Yes, but often not: costs are "socialized" (average tariffs over all consumers)

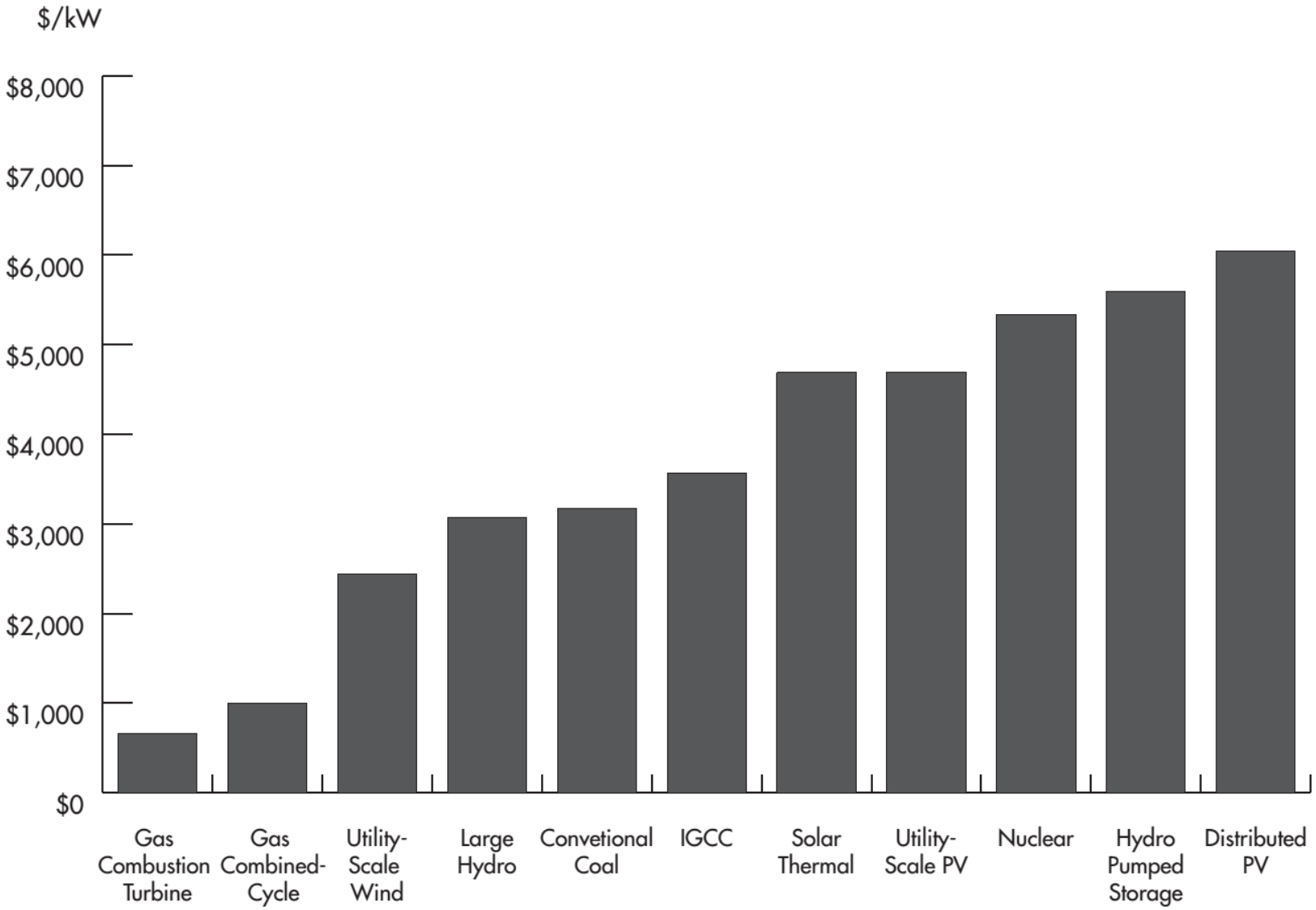
Thus not optimal (trade-off of efficiency, complexity and "fairness")

$$K: \quad f = \sum_{s} \alpha_s \mu_s$$

$$Q_S: \quad U_S'[Q_S] = c + \mu_S$$

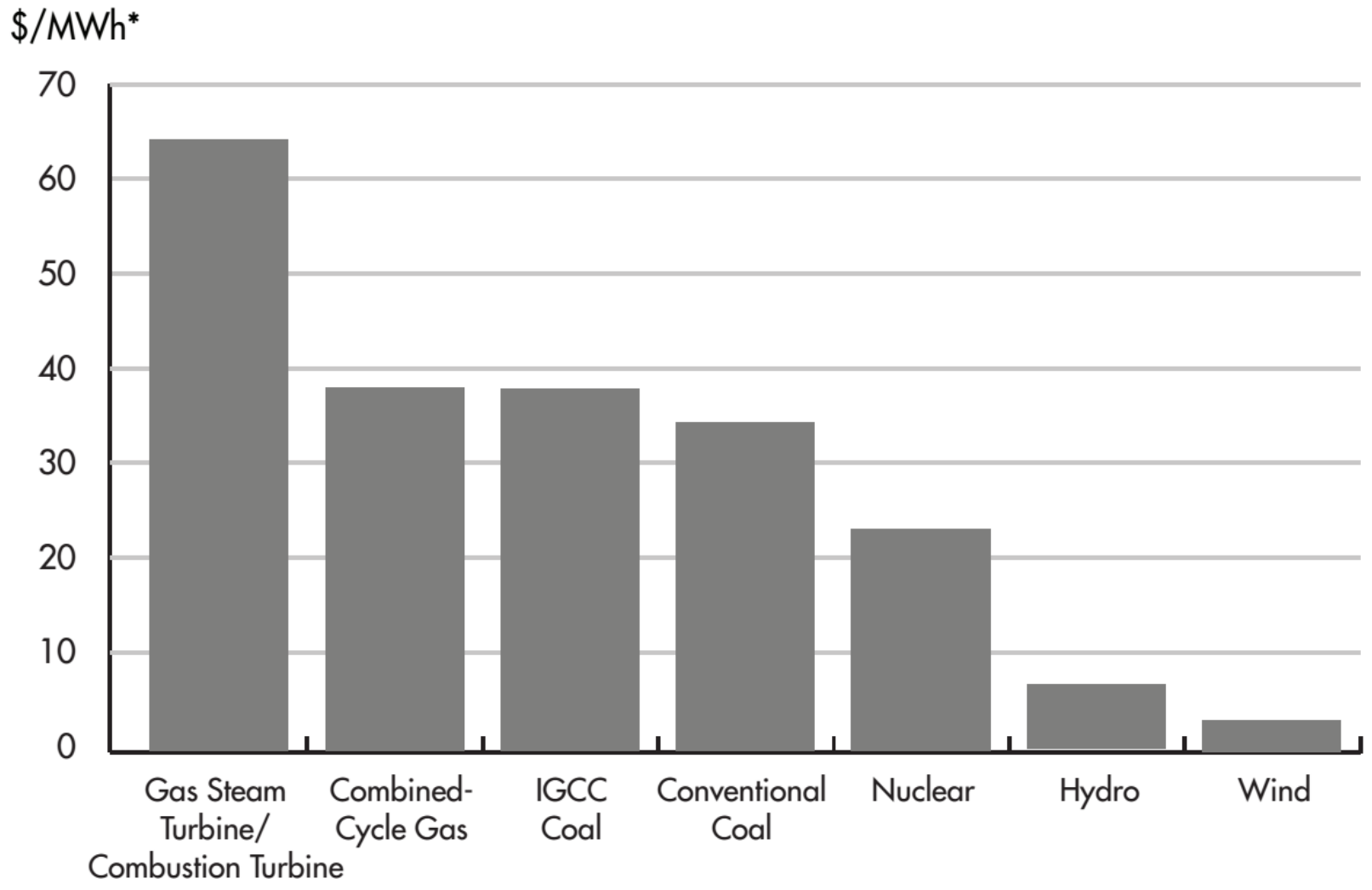
Optimal Dispatch

CAPITAL COSTS OF GENERATION TYPES



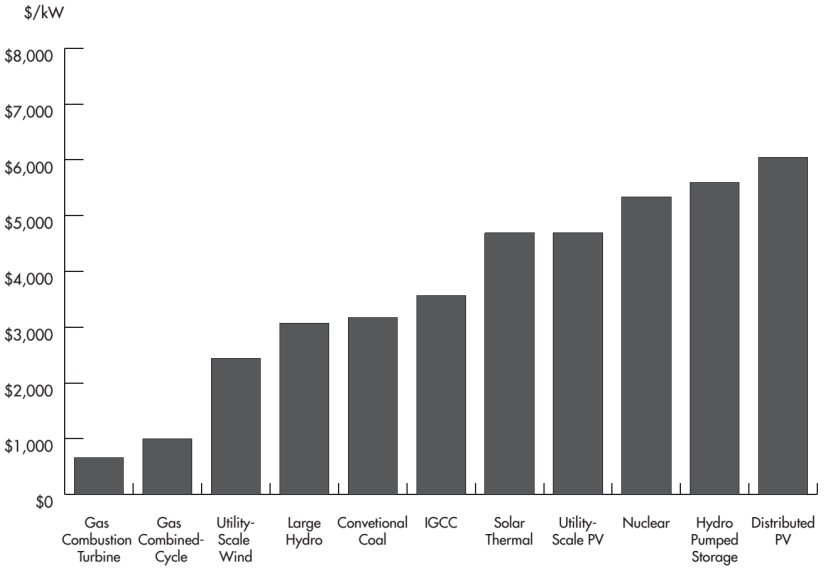
Source: EIA AEO 2011

VARIABLE OPERATING COSTS OF GENERATION



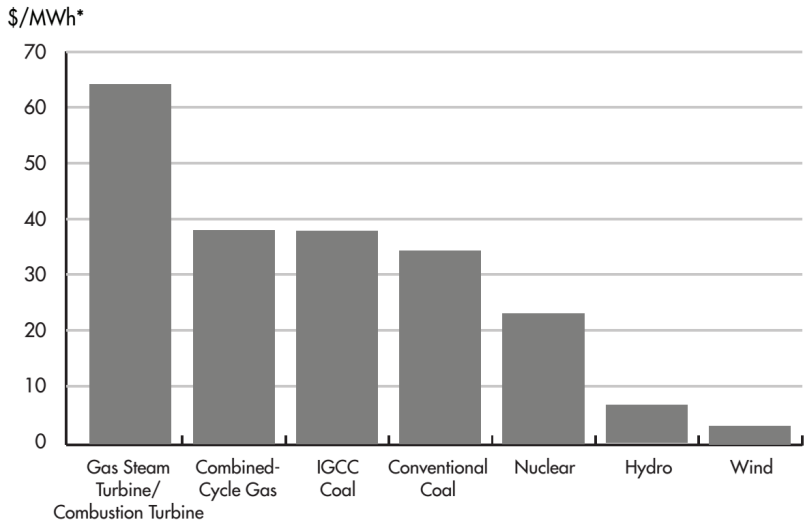
*Based on a gas price of $5.00/MMBtu

CAPITAL COSTS OF GENERATION TYPES



Source: EIA AEO 2011

VARIABLE OPERATING COSTS OF GENERATION

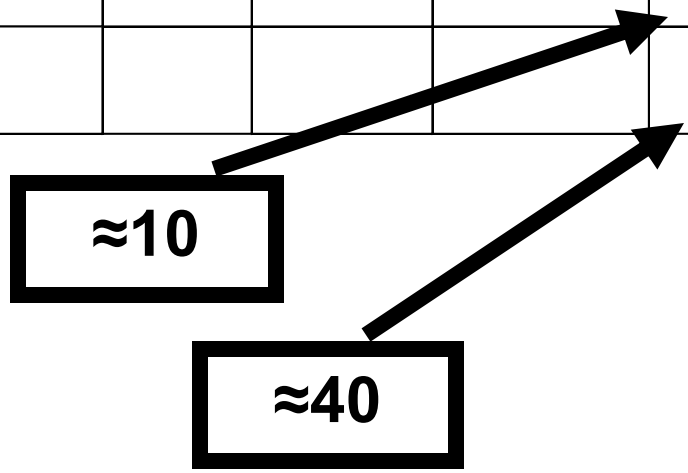


*Based on a gas price of $5.00/MMBtu

Levelized costs of generation

Technology Costs Table

Fixed cost	**Power (MW)**	years	Days/ year	Hrs/ day	Hrs / year	**total hours**	**FC/ MWh**
1,300,000,000							
5,000,000,000							



Multitude of generation types

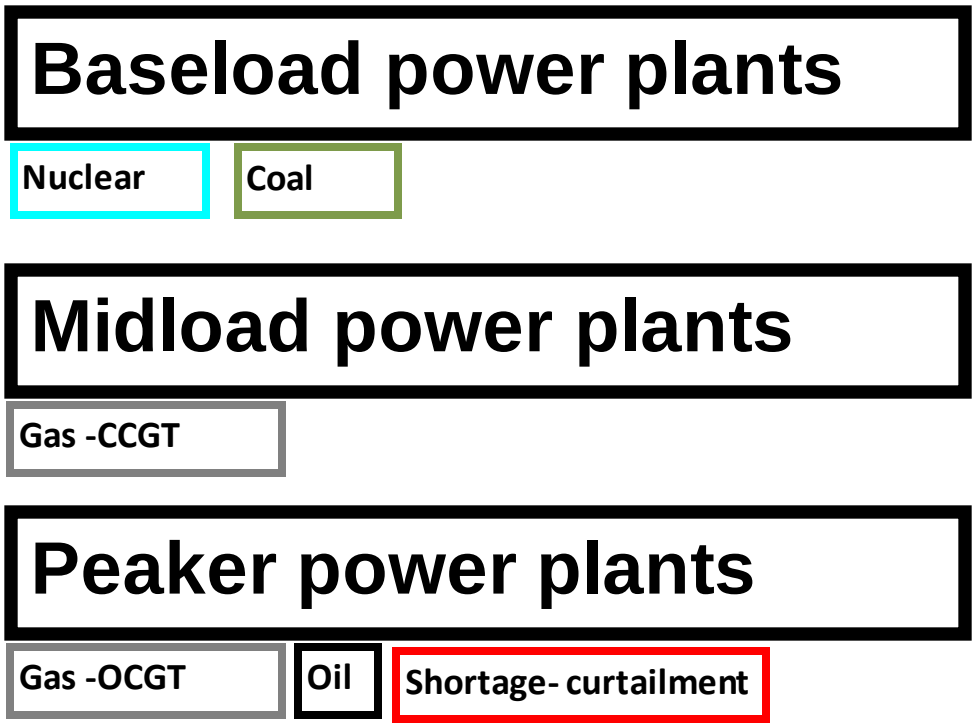
Technology Costs Table

	Fixed cost per MWh	Variable cost per MWh
Baseload	40	0
Midload	20	30
Peaker	10	50

Trade-off:

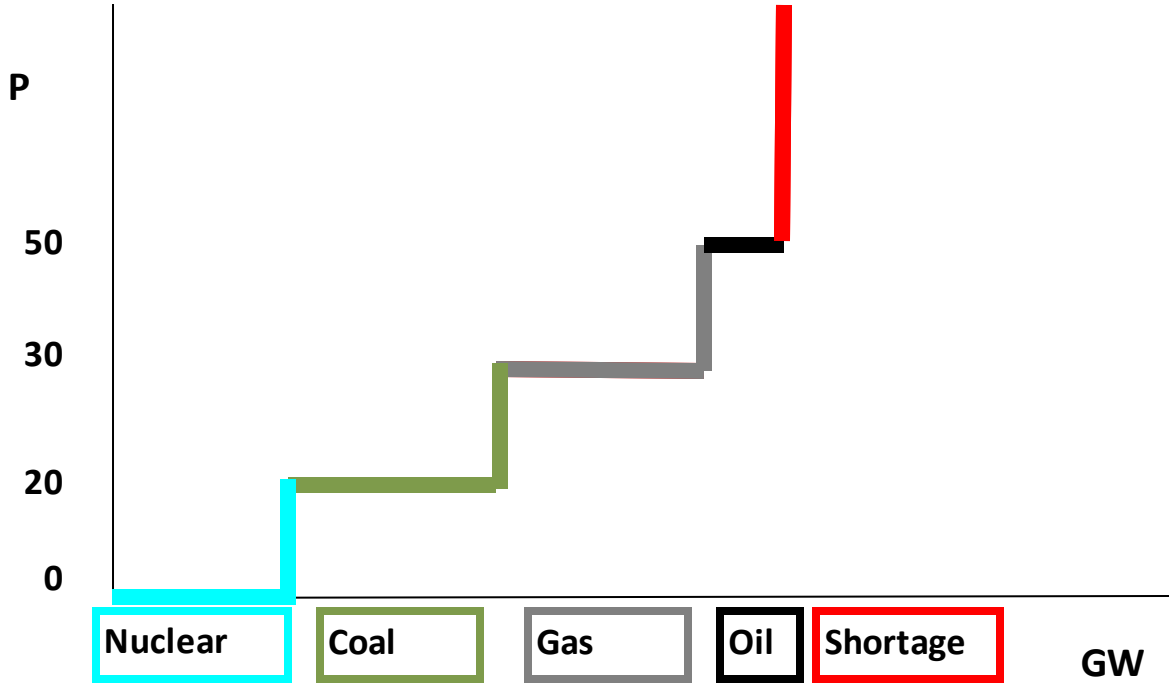
Economics of scale

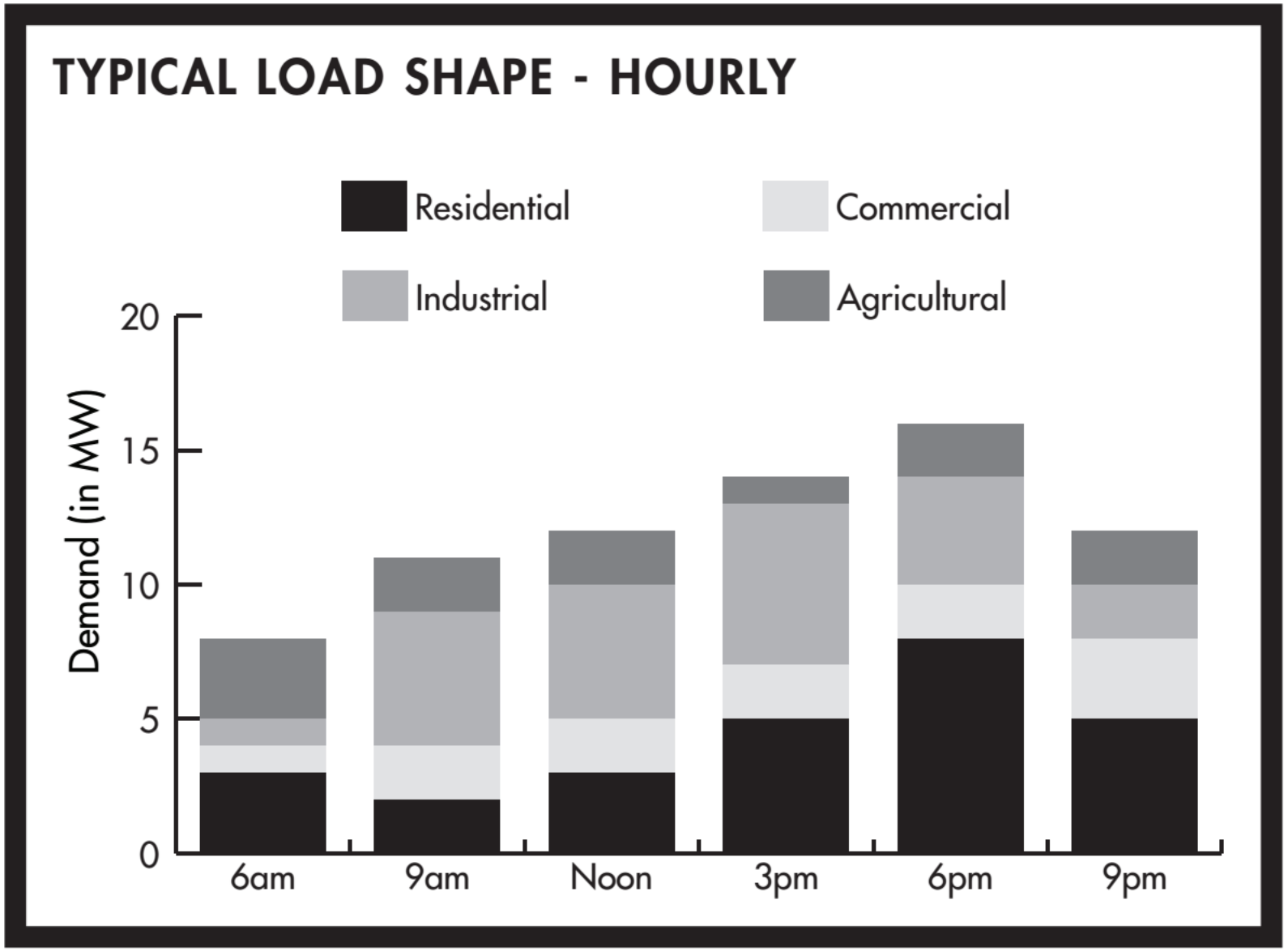
Flexibility



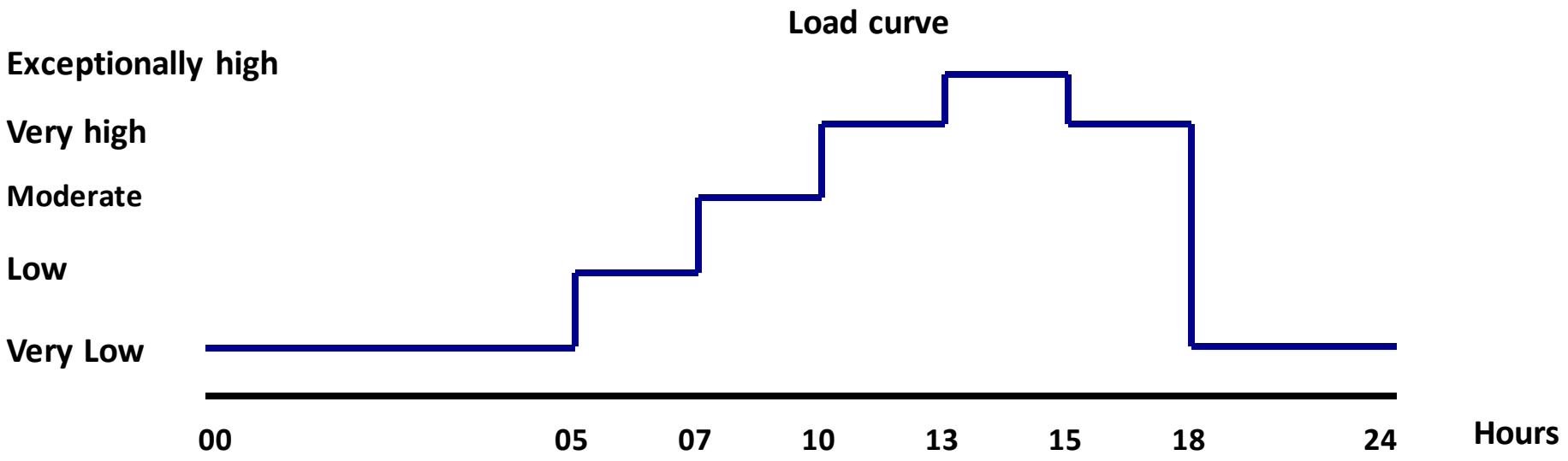
The supply stack

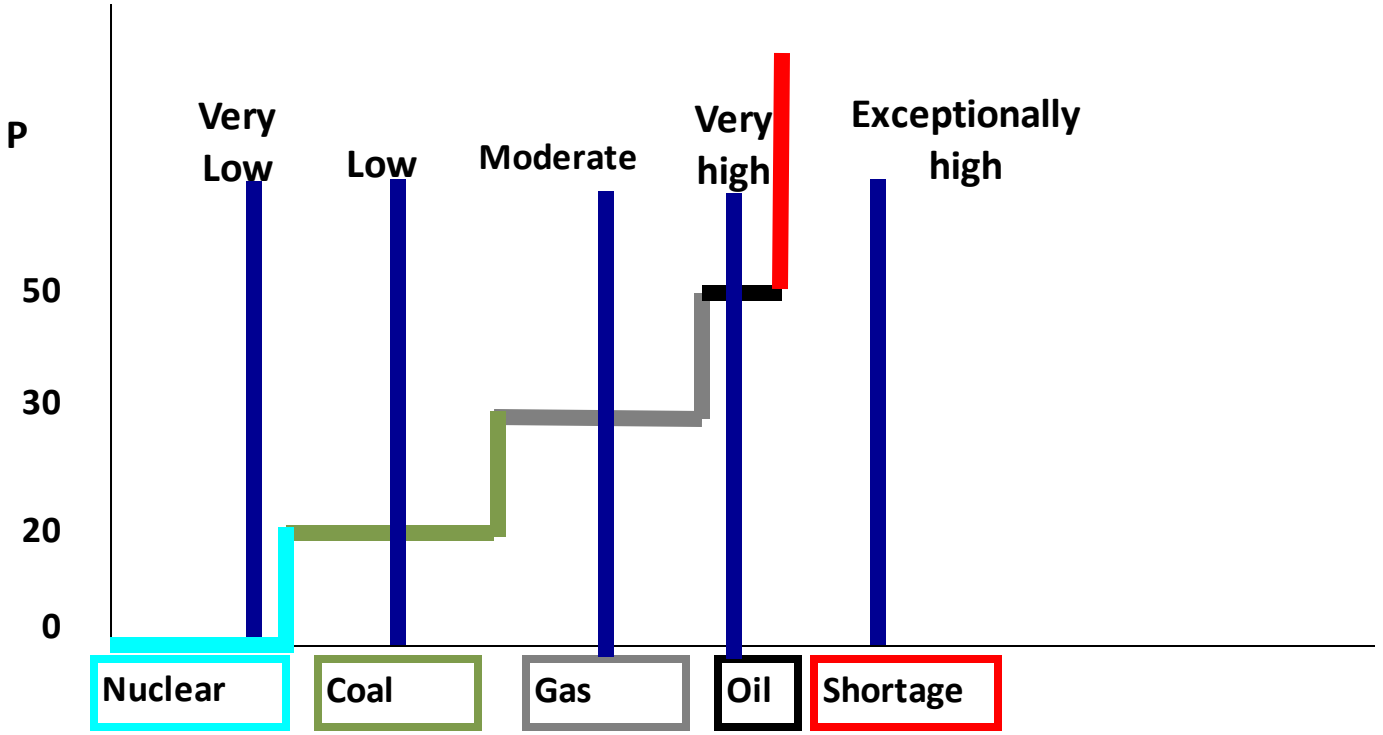
(also called "merit order")

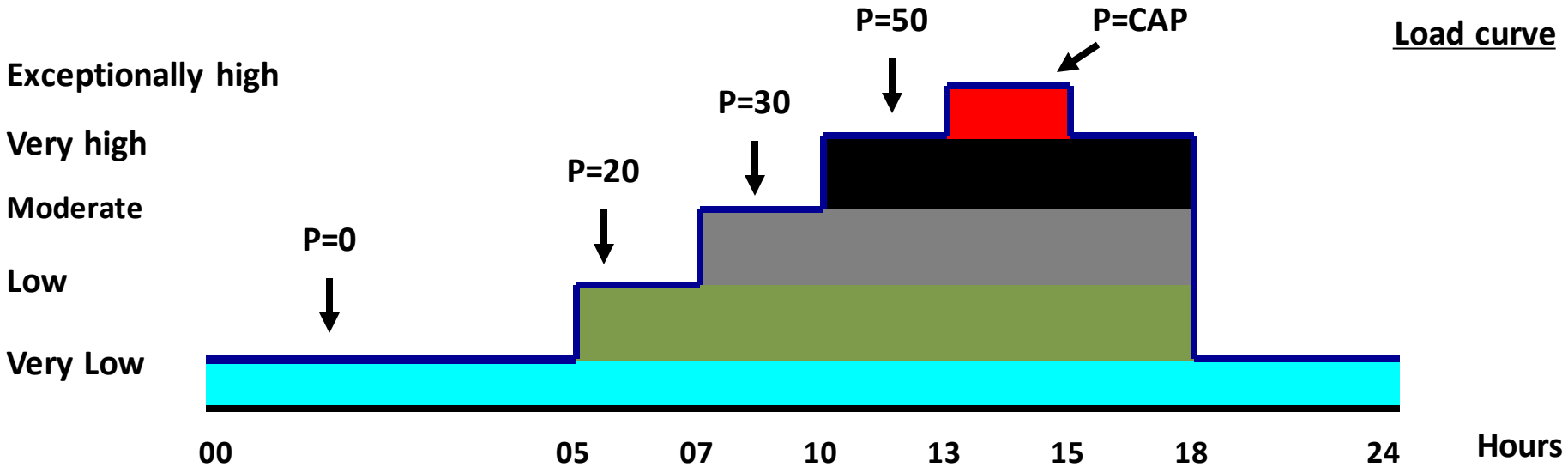


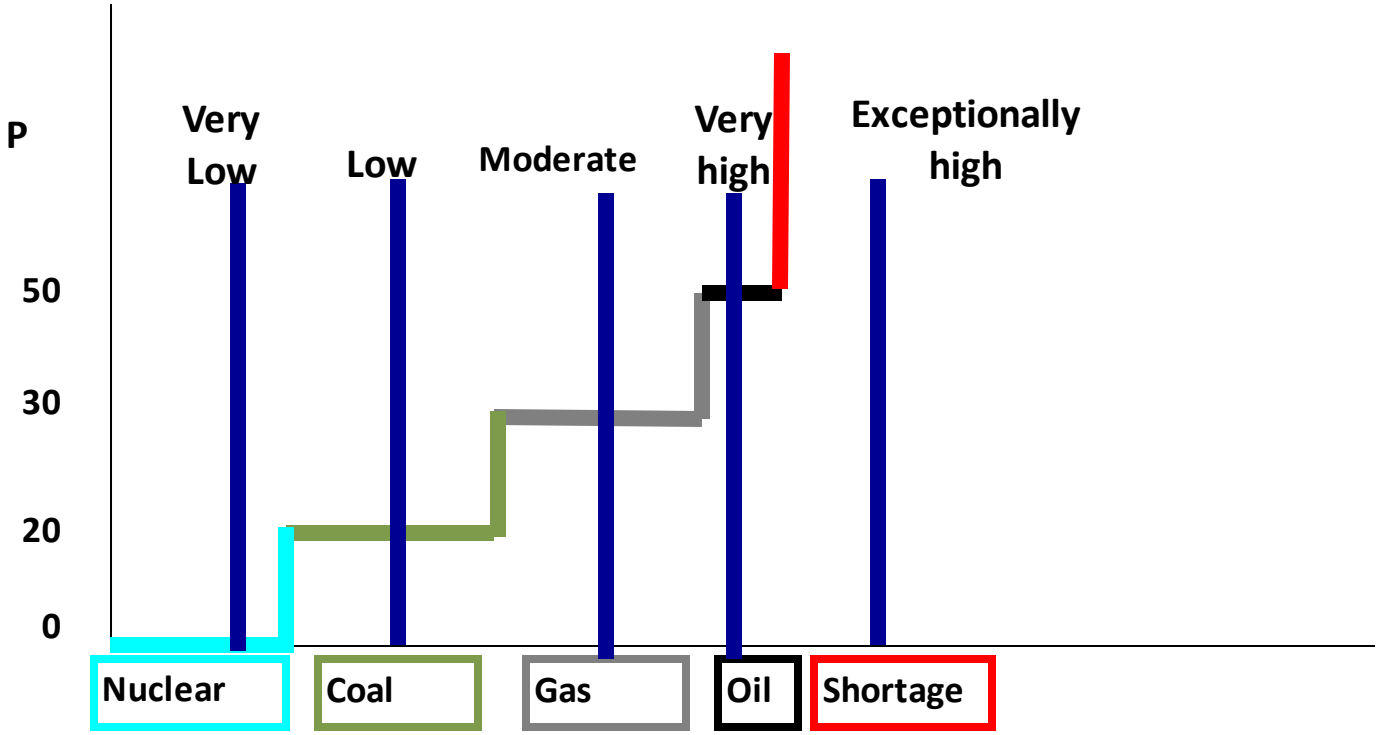

TYPICAL LOAD SHAPE - HOURLY
Residential
Commercial
Industrial
Agricultural
Demand (in MW)
20
15
10
5
0
6am
9am
Noon
3pm
6pm
9pm

Shively, p32.


Load curve
Exceptionally high
Very high
Moderate
Low
Very Low
00
05
07
10
13
15
18
24
Hours


P
50
30
20
0
Very Low
Low
Moderate
Very high
Exceptionally high
Nuclear
Coal
Gas
Oil
Shortage


Load curve
P=50
P=CAP
Exceptionally high
P=30
Very high
P=20
Moderate
P=0
Low
Very Low
00
05
07
10
13
15
18
24
Hours


P
Very Low
Low
Moderate
Very high
Exceptionally high
50
30
20
0
Nuclear
Coal
Gas
Oil
Shortage

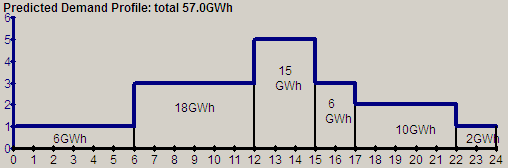
Monopoly treatment

You are Subject no.2 in Group no. 2 -- Period 1 of 4: There are - including you - 1 producers in your group}

CHOOSE: Choose generation plants and your bids

Remaining time [sec]: 87

Predicted Demand Profile: total 57.0GWh



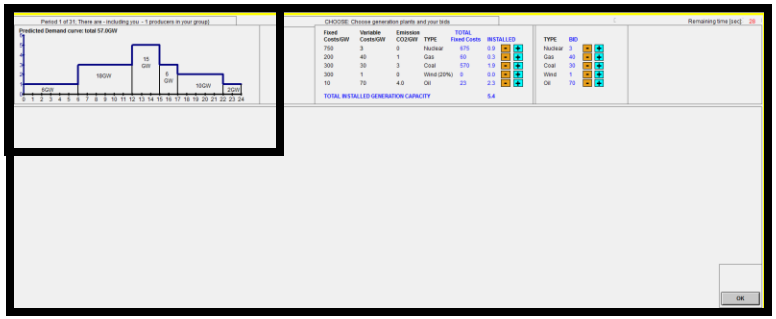
Fixed Costs/GW	Variable Costs/GWh	Emission CO2/GWh	TYPE	TOTAL Fixed Costs	INSTALLED	
750	3	0	Nuclear	675	0.9	- +
200	40	1	Gas	60	0.3	- +
300	30	3	Coal	570	1.9	- +
300	1	0	Wind (20%)	0	0.0	- +
10	70	4.0	Oil	23	2.3	- +

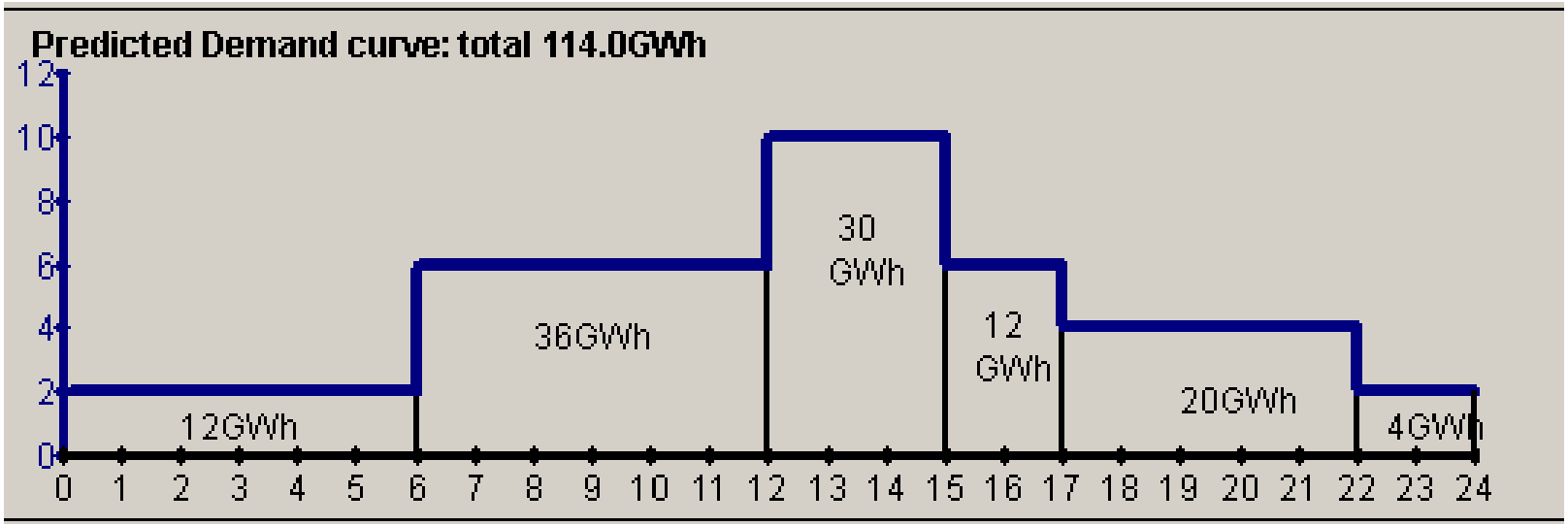
TOTAL INSTALLED GENERATION CAPACITY 5.4

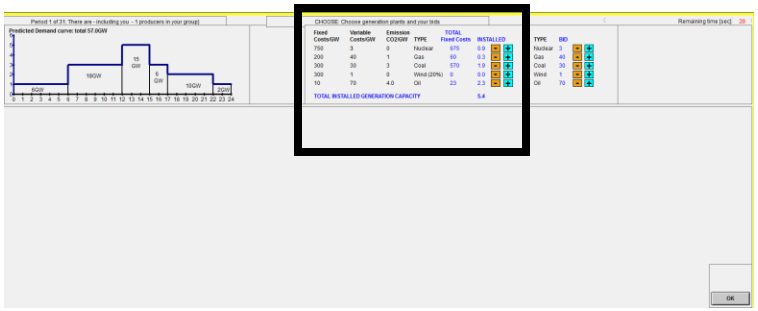
TYPE	BID
Nuclear	3
Gas	40
Coal	30
Wind	1
Oil	70

OK

18 of 24 - Clipboard
Item collected.




Predicted Demand curve: total 114.0GWh
12GWh
36GWh
30 GWh
12 GWh
20GWh
4GWh
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
0 2 4 6 8 10 12



Fixed Costs/GW	Variable Costs/GW	Emission CO2/GW	TYPE	TOTAL Fixed Costs	INSTALLED		
750	3	0	Nuclear	675	0.9	-	+
200	40	1	Gas	60	0.3	-	+
300	30	3	Coal	570	1.9	-	+
300	1	0	Wind (20%)	0	0.0	-	+
10	70	4.0	Oil	23	2.3	-	+

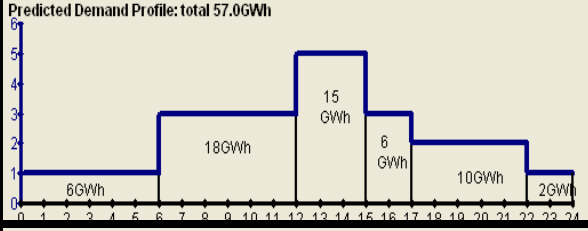
TOTAL INSTALLED GENERATION CAPACITY 5.4

You are Subject no.1 in Group no. 1 -- Period 2 of 10; There are - including you - 1 producers in your

CHOOSE: Choose generation plants and your bids

Remaining time [sec]: 147

Predicted Demand Profile: total 57.0GWh



Fixed Costs/GW	Variable Costs/GW	Emission CO2/GW	TYPE	TOTAL Fixed Costs	INSTALLED
750	3	0	Nuclear	675	0.9
200	40	1	Gas	60	0.3
300	30	3	Coal	570	1.9
15	1	0	Wind (20%)	0	0.0
10	70	4.0	Oil	15	1.5
TOTAL INSTALLED GENERATION CAPACITY					4.6

TYPE	BID
Nuclear	3
Gas	40
Coal	30
Wind	1
Oil	70

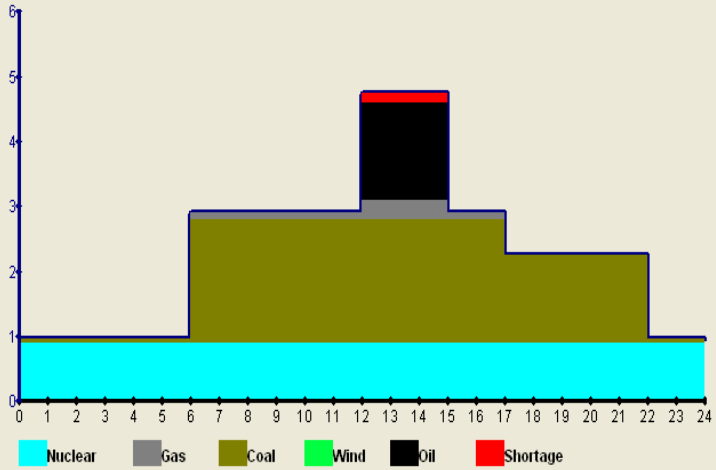
Results LAST ROUND

Realized Demand Profile: total 56.4GWh
Average price 64

Show only my Stack

Don't show Quasi-Rent (QR)

Don't show Price (P)



TYPE	Installed Capacity	Available Capacity	Capacity Factor	Profit	Emission CO2
Nuclear	0.9	0.9	1.00	304	0
Gas	0.3	0.3	0.25	39	2
Coal	1.9	1.9	0.62	266	84
Wind (20%)	0.0	0.0	0.00	0	0
Oil	1.5	1.5	0.12	345	18
TOTAL PROFIT				954	104

The highest profit this round is by Subject no.1 with 954

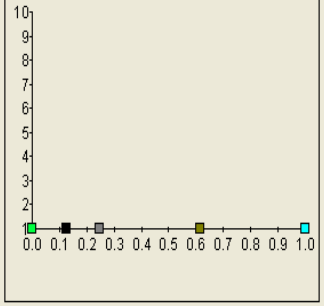
The lowest profit from all groups was 954
The average profit over all groups was 954

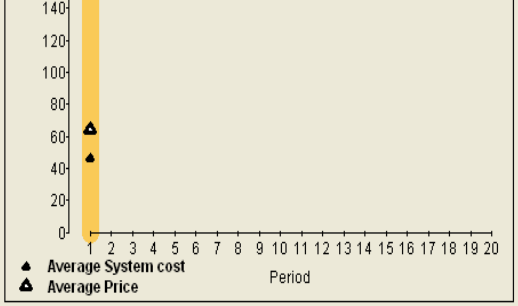
the most efficient group: Group no.1 with production cost of 46 per GWh

The production cost of your system is 46 per GWh

Your profit is 17 per GWh

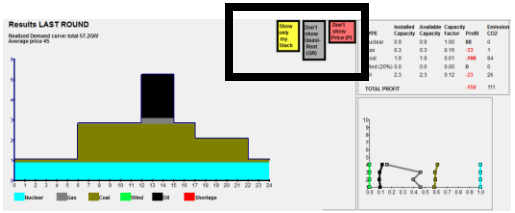
The average price in your group is 64 per GWh

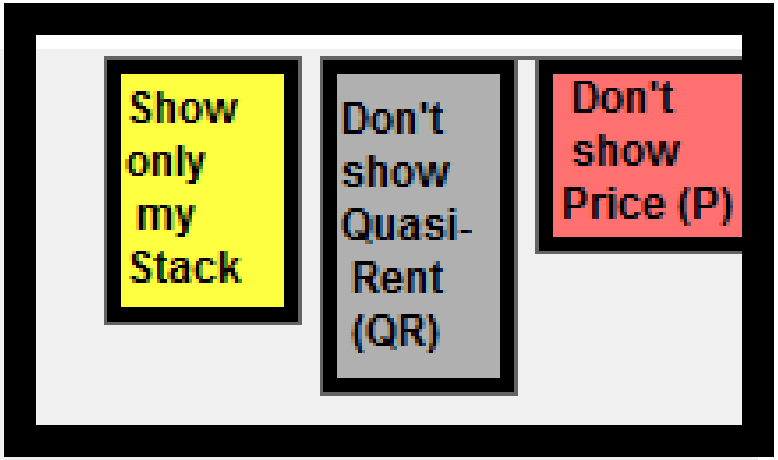


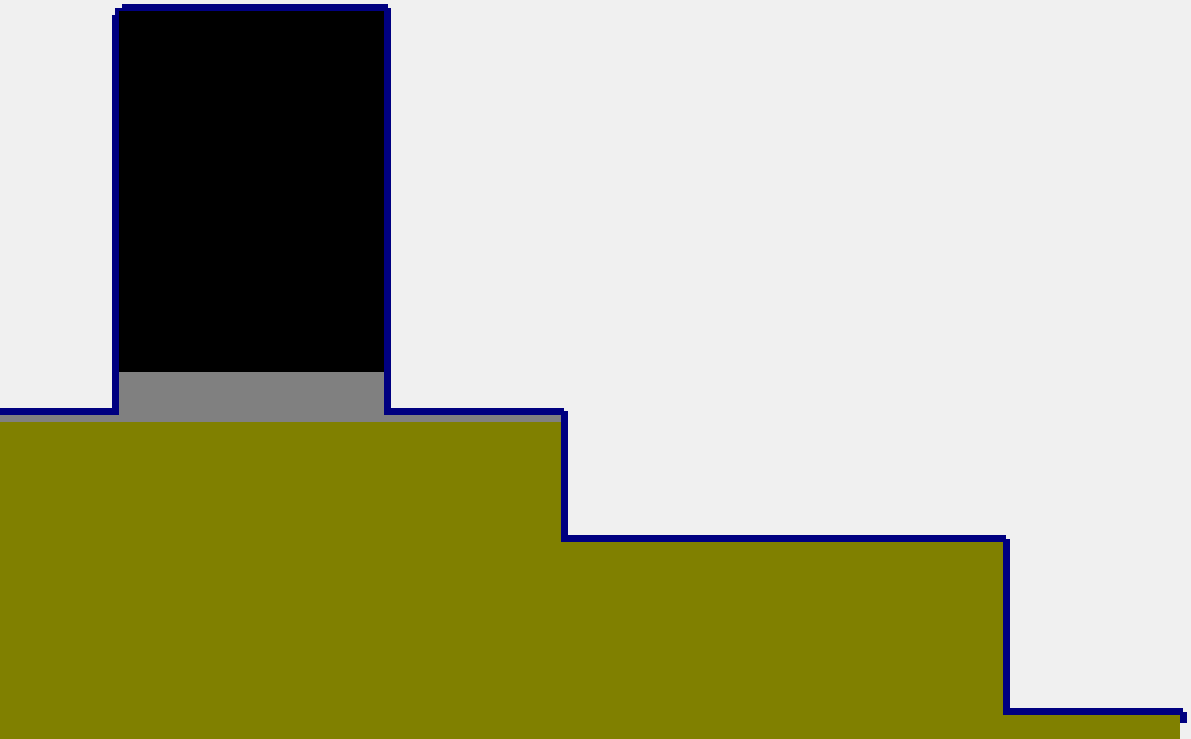


OK

Period	Predicted Demand (GW)	Realized Demand (GW)	Nuclear Installed	Gas Installed	Coal Installed	Wind Installed	Oil Installed	Nuclear Bid	Gas Bid	Coal Bid	Wind Bid	Oil Bid	Nuclear Profit	Gas Profit	Coal Profit	Wind Profit	Oil Profit	Profit	TotalProfit
1	57.0	56.4	0.9	0.3	1.9	0.0	1.5	3	40	30	1	70	304	39	266	0	345	5954	5954


Results LAST ROUND
Show only my Stack
Don't show Quasi-Rent (QR)
Don't show Price (P)


Show only my Stack
Don't show Quasi-Rent (QR)
Don't show Price (P)

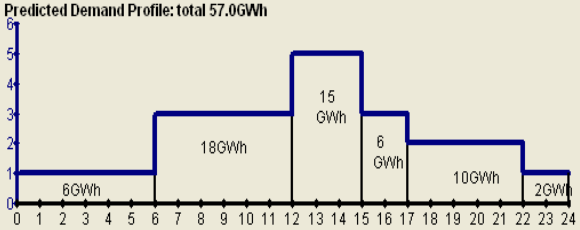


You are Subject no.1 in Group no. 1 -- Period 2 of 10; There are - including you - 1 producers in your

CHOOSE: Choose generation plants and your bids

Remaining time [sec]: 147

Predicted Demand Profile: total 57.0GWh



Fixed Costs/GW	Variable Costs/GW	Emission CO2/GW	TYPE	TOTAL Fixed Costs	INSTALLED
750	3	0	Nuclear	675	0.9
200	40	1	Gas	60	0.3
300	30	3	Coal	570	1.9
15	1	0	Wind (20%)	0	0.0
10	70	4.0	Oil	15	1.5
TOTAL INSTALLED GENERATION CAPACITY					4.6

TYPE	BID
Nuclear	3
Gas	40
Coal	30
Wind	1
Oil	70

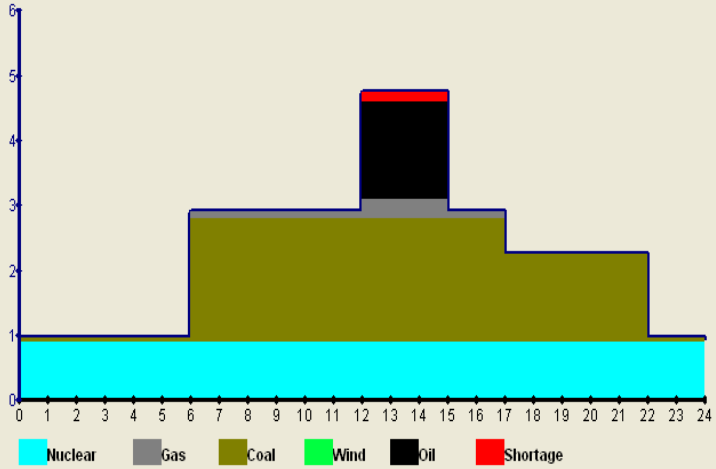
Results LAST ROUND

Realized Demand Profile: total 56.4GWh
Average price 64

Show only my Stack

Don't show Quasi-Rent (QR)

Don't show Price (P)



TYPE	Installed Capacity	Available Capacity	Capacity Factor	Profit	Emission CO2
Nuclear	0.9	0.9	1.00	304	0
Gas	0.3	0.3	0.25	39	2
Coal	1.9	1.9	0.62	266	84
Wind (20%)	0.0	0.0	0.00	0	0
Oil	1.5	1.5	0.12	345	18
TOTAL PROFIT				954	104

The highest profit this round is by Subject no.1 with 954

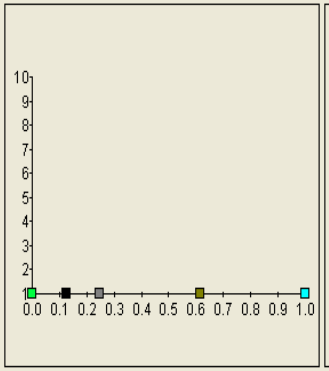
The lowest profit from all groups was 954
The average profit over all groups was 954

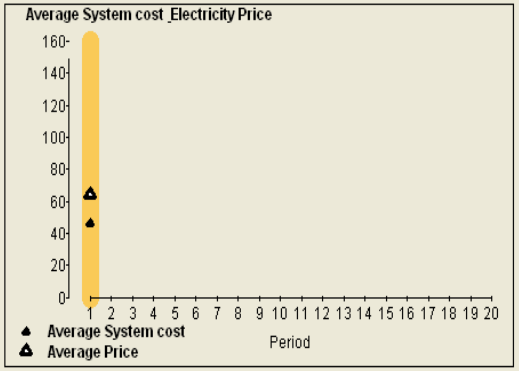
the most efficient group: Group no.1 with production cost of 46 per GWh

The production cost of your system is 46 per GWh

Your profit is 17 per GWh

The average price in your group is 64 per GWh





OK

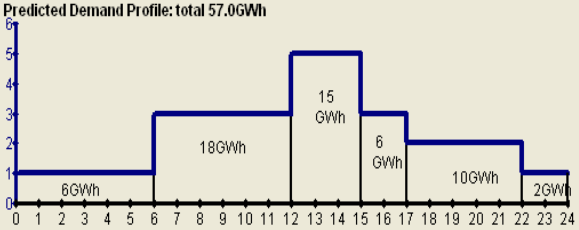
Period	Predicted Demand (GW)	Realized Demand (GW)	Nuclear Installed	Gas Installed	Coal Installed	Wind Installed	Oil Installed	Nuclear Bid	Gas Bid	Coal Bid	Wind Bid	Oil Bid	Nuclear Profit	Gas Profit	Coal Profit	Wind Profit	Oil Profit	Profit	TotalProfit
1	57.0	56.4	0.9	0.3	1.9	0.0	1.5	3	40	30	1	70	304	39	266	0	345	5954	5954

You are Subject no.1 in Group no. 1 -- Period 2 of 10; There are - including you - 1 producers in your

CHOOSE: Choose generation plants and your bids

Remaining time [sec]: 127

Predicted Demand Profile: total 57.0GWh

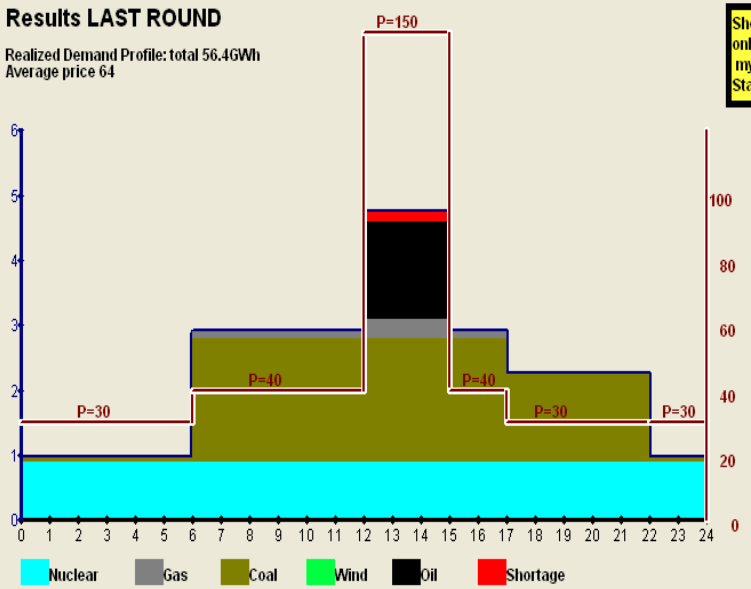


Fixed Costs/GW	Variable Costs/GW	Emission CO2/GW	TYPE	TOTAL Fixed Costs	INSTALLED
750	3	0	Nuclear	675	0.9
200	40	1	Gas	60	0.3
300	30	3	Coal	570	1.9
15	1	0	Wind (20%)	0	0.0
10	70	4.0	Oil	15	1.5
TOTAL INSTALLED GENERA					4.6

TYPE	BID
Nuclear	3
Gas	40
Coal	30
Wind	1
Oil	70

Results LAST ROUND

Realized Demand Profile: total 56.4GWh
Average price 64



Show only my Stack

Show Price (P)

	Installed Capacity	Available Capacity	Capacity Factor	Profit	Emission CO2
Nuclear	0.9	0.9	1.00	304	0
Gas	0.3	0.3	0.25	39	2
Coal	1.9	1.9	0.62	266	84
Wind (20%)	0.0	0.0	0.00	0	0
Oil	1.5	1.5	0.12	345	18
TOTAL PROFIT				954	104

The highest profit this round is by Subject no.1 with 954

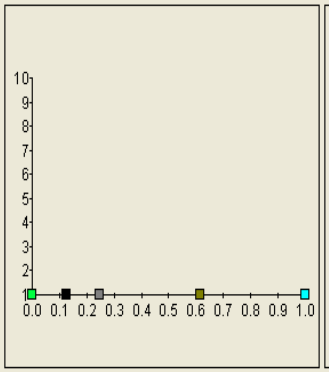
The lowest profit from all groups was 954
The average profit over all groups was 954

the most efficient group: Group no.1 with production cost of 46 per GWh

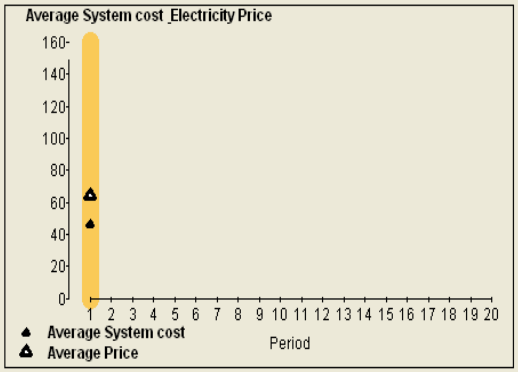
The production cost of your system is 46 per GWh

Your profit is 17 per GWh

The average price in your group is 64 per GWh



Average System cost _Electricity Price



OK

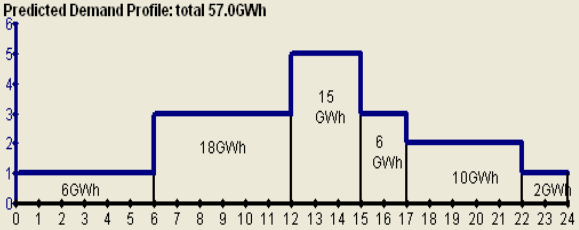
Period	Predicted Demand (GW)	Realized Demand (GW)	Nuclear Installed	Gas Installed	Coal Installed	Wind Installed	Oil Installed	Nuclear Bid	Gas Bid	Coal Bid	Wind Bid	Oil Bid	Nuclear Profit	Gas Profit	Coal Profit	Wind Profit	Oil Profit	Profit	TotalProfit
1	57.0	56.4	0.9	0.3	1.9	0.0	1.5	3	40	30	1	70	304	39	266	0	345	5954	5954

You are Subject no.1 in Group no. 1 -- Period 2 of 10; There are - including you - 1 producers in your

CHOOSE: Choose generation plants and your bids

Remaining time [sec]: 113

Predicted Demand Profile: total 57.0GWh



Fixed Costs/GW	Variable Costs/GW	Emission CO2/GW	TYPE	TOTAL Fixed Costs	INSTALLED
750	3	0	Nuclear	675	0.9
200	40	1	Gas	60	0.3
300	30	3	Coal	570	1.9
15	1	0	Wind (20%)	0	0.0
10	70	4.0	Oil	15	1.5
TOTAL INSTALL					4.6

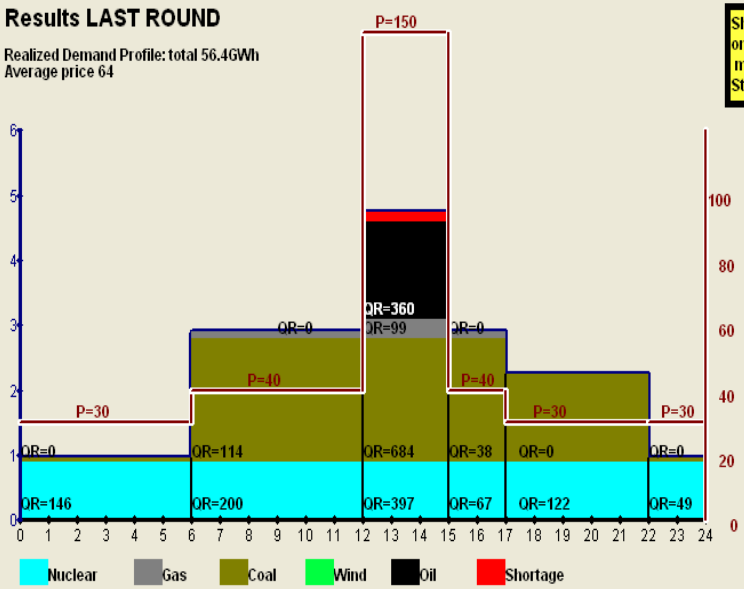
TYPE	BID
Nuclear	3
Gas	40
Coal	30
Wind	1
Oil	70

Show Quasi-Rent (QR)

Show Price (P)

Results LAST ROUND

Realized Demand Profile: total 56.4GWh
Average price 64



TYP	Installed Capacity	Available Capacity	Capacity Factor	Profit	Emission CO2
Nuc	0.9	0.9	1.00	304	0
Gas	0.3	0.3	0.25	39	2
Coa	1.9	1.9	0.62	266	84
%)	0.0	0.0	0.00	0	0
	1.5	1.5	0.12	345	18
TOTAL PROFIT				954	104

The highest profit this round is by Subject no.1 with 954

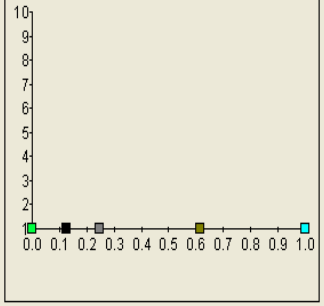
The lowest profit from all groups was 954
The average profit over all groups was 954

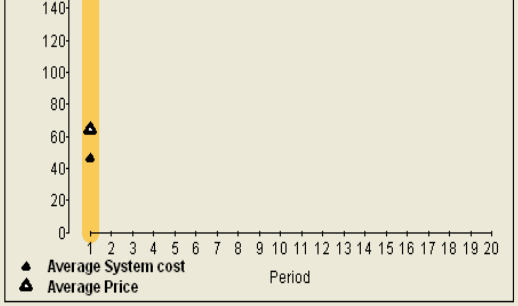
the most efficient group: Group no.1 with production cost of 46 per GWh

The production cost of your system is 46 per GWh

Your profit is 17 per GWh

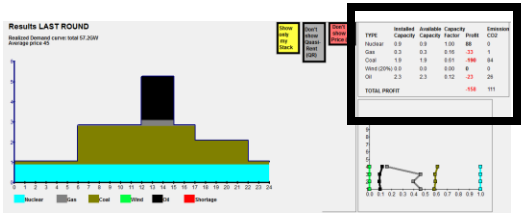
The average price in your group is 64 per GWh



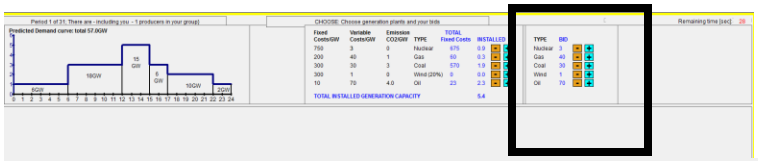


OK

Period	Predicted Demand (GW)	Realized Demand (GW)	Nuclear Installed	Gas Installed	Coal Installed	Wind Installed	Oil Installed	Nuclear Bid	Gas Bid	Coal Bid	Wind Bid	Oil Bid	Nuclear Profit	Gas Profit	Coal Profit	Wind Profit	Oil Profit	Profit	TotalProfit
1	57.0	56.4	0.9	0.3	1.9	0.0	1.5	3	40	30	1	70	304	39	266	0	345	5954	5954



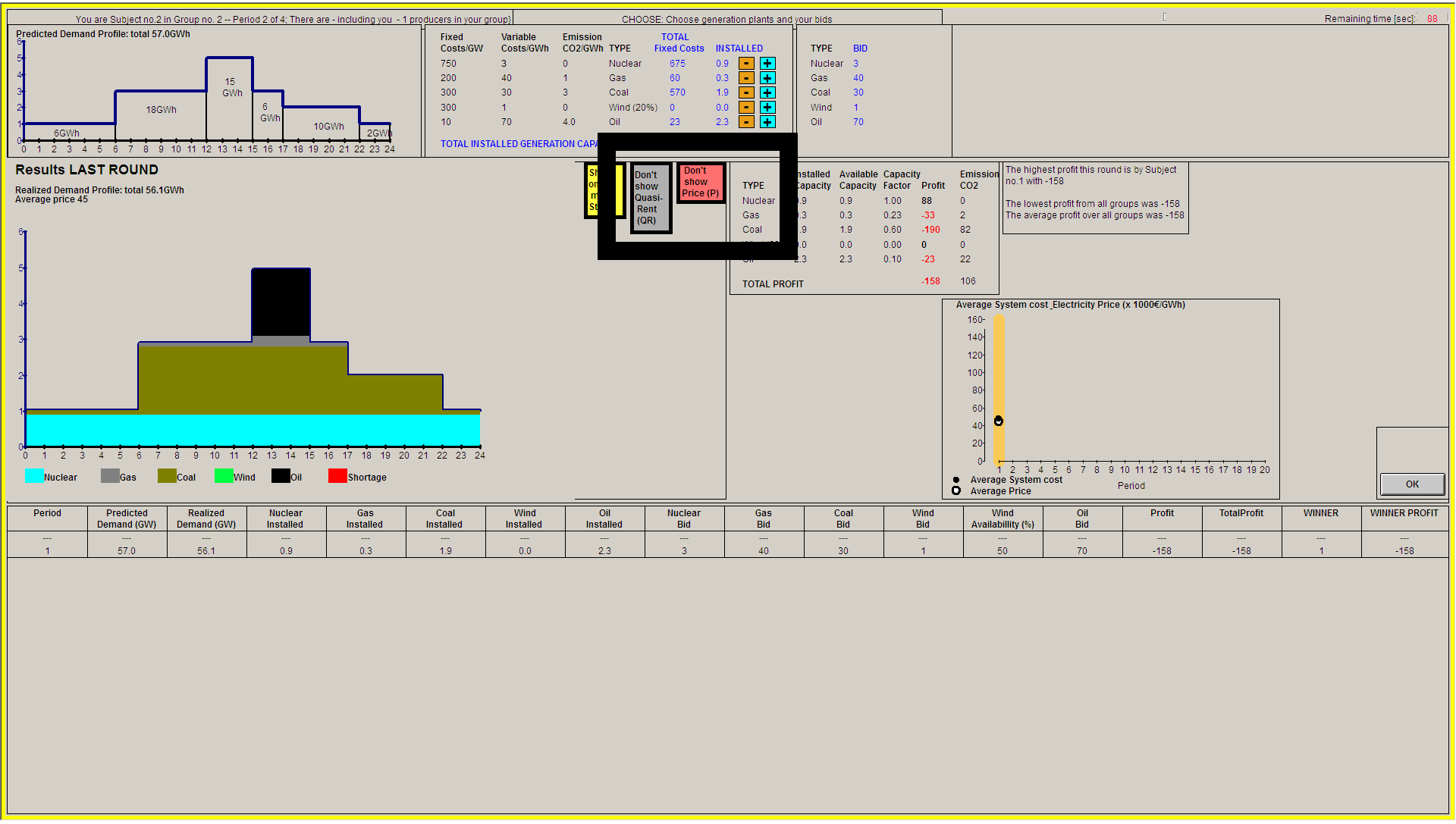
TYPE	Installed Capacity	Available Capacity	Capacity Factor	Profit	Emission CO2
Nuclear	0.9	0.9	1.00	16	0
Gas	0.3	0.3	0.12	-33	1
Coal	1.9	1.9	0.57	-342	79
Wind (20%)	0.0	0.0	0.00	0	0
Oil	2.3	2.3	0.12	-23	28
TOTAL PROFIT				-382	107



TYPE	BID		
Nuclear	3	-	+
Gas	40	-	+
Coal	30	-	+
Wind	1	-	+
Oil	70	-	+

Minimal price you accept

Monopoly treatment



Period	Predicted Demand (GW)	Realized Demand (GW)	Nuclear Installed	Gas Installed	Coal Installed	Wind Installed	Oil Installed	Nuclear Bid	Gas Bid	Coal Bid	Wind Bid	Wind Availabillity (%)	Oil Bid	Profit	TotalProfit	WINNER	WINNER PROFIT
---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
1	57.0	56.1	0.9	0.3	1.9	0.0	2.3	3	40	30	1	50	70	-158	-158	1	-158

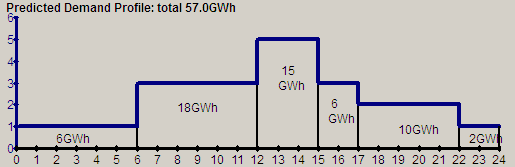
Monopoly treatment

You are Subject no.1 in Group no. 1 -- Period 2 of 4; There are - including you - 1 producers in your group}

CHOOSE: Choose generation plants and your bids

Remaining time [sec]: 85

Predicted Demand Profile: total 57.0GWh



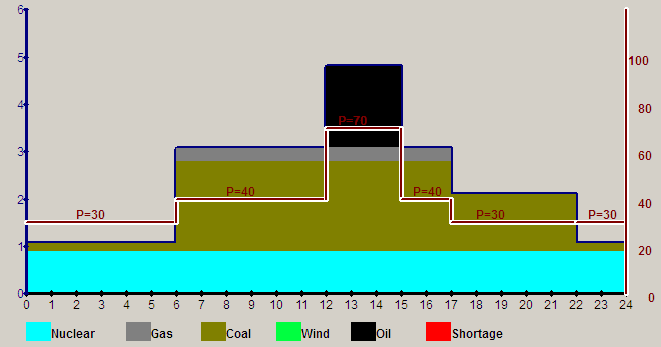
Fixed Costs/GW	Variable Costs/GWh	Emission CO2/GWh	TYPE	TOTAL Fixed Costs	INSTALLED
750	3	0	Nuclear	675	0.9
200	40	1	Gas	60	0.3
300	30	3	Coal	570	1.9
300	1	0	Wind (20%)	0	0.0
10	70	4.0	Oil	23	2.3

TOTAL INSTALLED GENERATION CAPACITY 5.4

TYPE	BID
Nuclear	3
Gas	40
Coal	30
Wind	1
Oil	70

Results LAST ROUND

Realized Demand Profile: total 57.9GWh
Average price 44



Show only my Stack

Don't show Quasi-Rent (QR)

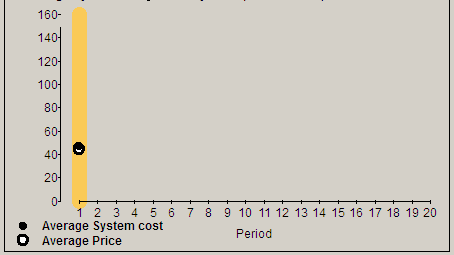
Show Price (P)

TYPE	Installed Capacity	Available Capacity	Capacity Factor	Profit	Emission CO2
Nuclear	0.9	0.9	1.00	88	0
Gas	0.3	0.3	0.42	-33	3
Coal	1.9	1.9	0.62	-190	85
Wind (20%)	0.0	0.0	0.00	0	0
Oil	2.3	2.3	0.09	-23	20
TOTAL PROFIT				-158	108

The highest profit this round is by Subject no.1 with -158

The lowest profit from all groups was -158
The average profit over all groups was -158

Average System cost _Electricity Price (x 1000€/GWh)



OK

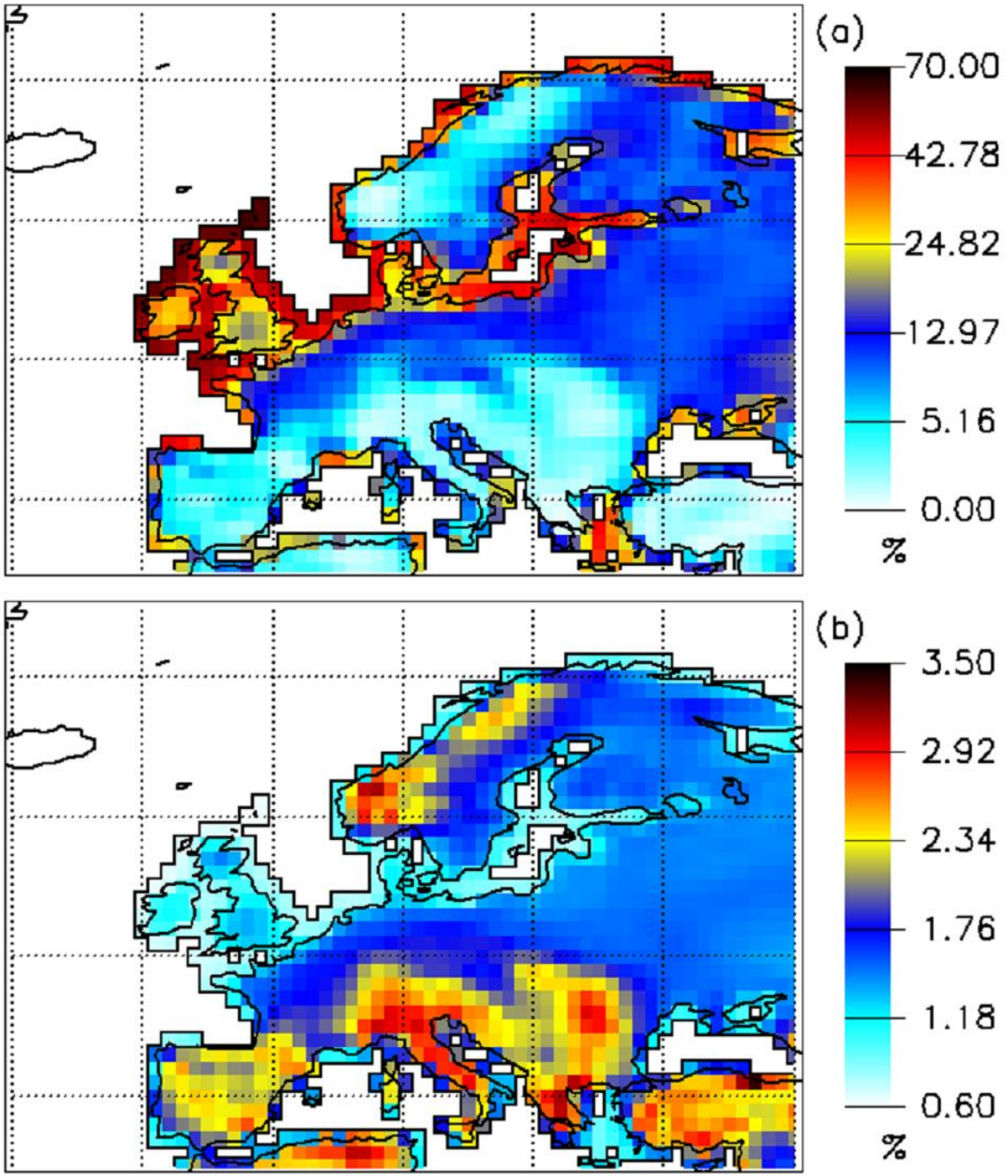
Period	Predicted Demand (GW)	Realized Demand (GW)	Nuclear Installed	Gas Installed	Coal Installed	Wind Installed	Oil Installed	Nuclear Bid	Gas Bid	Coal Bid	Wind Bid	Wind Availability (%)	Oil Bid	Profit	TotalProfit	WINNER	WINNER PROFIT
---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
1	57.0	57.9	0.9	0.3	1.9	0.0	2.3	3	40	30	1	60	70	-158	-158	1	-158

Monopoly treatment

Fixed Costs/GW	Variable Costs/GWh	Emission CO2/GWh	TYPE	TOTAL Fixed Costs	INSTALLED		
750	3	0	Nuclear	675	0.9	-	+
200	40	1	Gas	60	0.3	-	+
300	30	3	Coal	570	1.9	-	+
300	1	0	Wind (20%)		0.0	-	+
[illegible]	[illegible]	[illegible]	[illegible]	23	2.3	-	+

TOTAL INSTALLED GENERATION CAPACITY 5.4

TYPE	BID
Nuclear	3
Gas	40
Coal	30
Wind	1
Oil	70


(a)
70.00
42.78
24.82
12.97
5.16
0.00
%
(b)
3.50
2.92
2.34
1.76
1.18
0.60
%

Monopoly- Subsidy treatment

Fixed Costs/GW	Variable Costs/GWh	Emission CO2/GWh	TYPE	TOTAL Fixed Costs	INSTALLED		
750	3	0	Nuclear	675	0.9	-	+
200	40	1	Gas	60	0.3	-	+
300	30	3	Coal	570	1.9	-	+
10	1	0	Wind (20%)	0	0.0	-	+
10	70	4.0	Oil	23	2.3	-	+
TOTAL INSTALLED GENERATION CAPACITY					5.4		

TYPE	BID
Nuclear	3
Gas	40
Coal	30
Wind	1
Oil	70

Fixed Costs/GW	Variable Costs/GWh	Emission CO2/GWh	TYPE	TOTAL Fixed Costs	INSTALLED		
750	3	0	Nuclear	675	0.9	-	+
200	40	1	Gas	60	0.3	-	+
300	30	3	Coal	570	1.9	-	+
300	1	0	Wind (20%)		0.0	-	+
				23	2.3	-	+
TOTAL INSTALLED GENERATION CAPACITY					5.4		

TYPE	BID
Nuclear	3
Gas	40
Coal	30
Wind	1
Oil	70

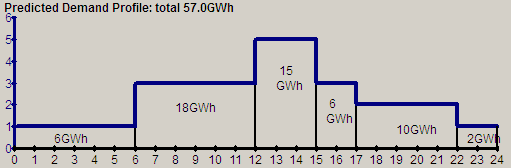
Duopoly treatment

You are Subject no.2 in Group no. 2 -- Period 1 of 4: There are - including you - 1 producers in your group}

CHOOSE: Choose generation plants and your bids

Remaining time [sec]: 87

Predicted Demand Profile: total 57.0GWh



Fixed Costs/GW	Variable Costs/GWh	Emission CO2/GWh	TYPE	TOTAL Fixed Costs	INSTALLED		
750	3	0	Nuclear	675	0.9	-	+
200	40	1	Gas	60	0.3	-	+
300	30	3	Coal	570	1.9	-	+
300	1	0	Wind (20%)	0	0.0	-	+
10	70	4.0	Oil	23	2.3	-	+

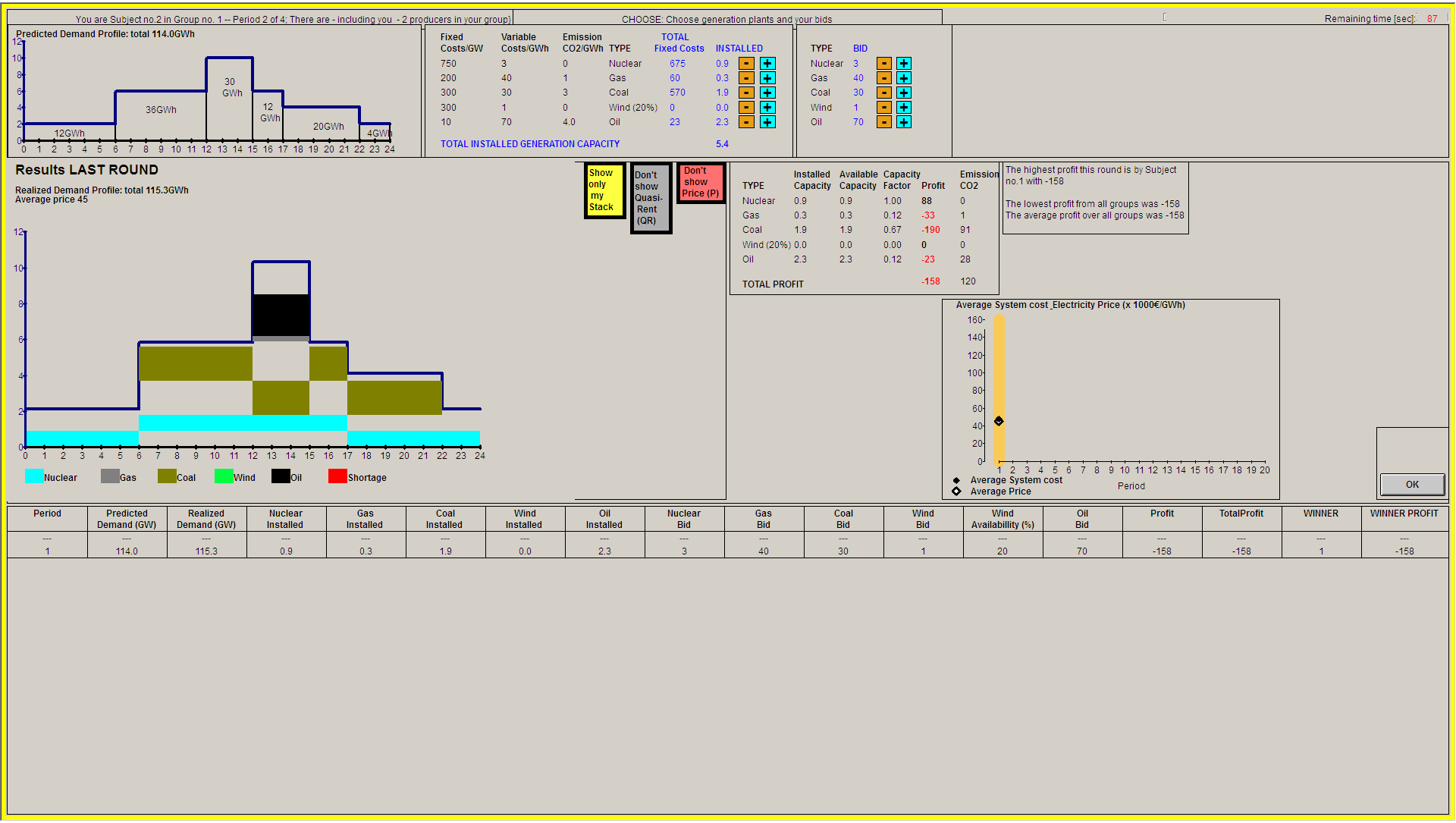
TOTAL INSTALLED GENERATION CAPACITY 5.4

TYPE	BID
Nuclear	3
Gas	40
Coal	30
Wind	1
Oil	70

OK

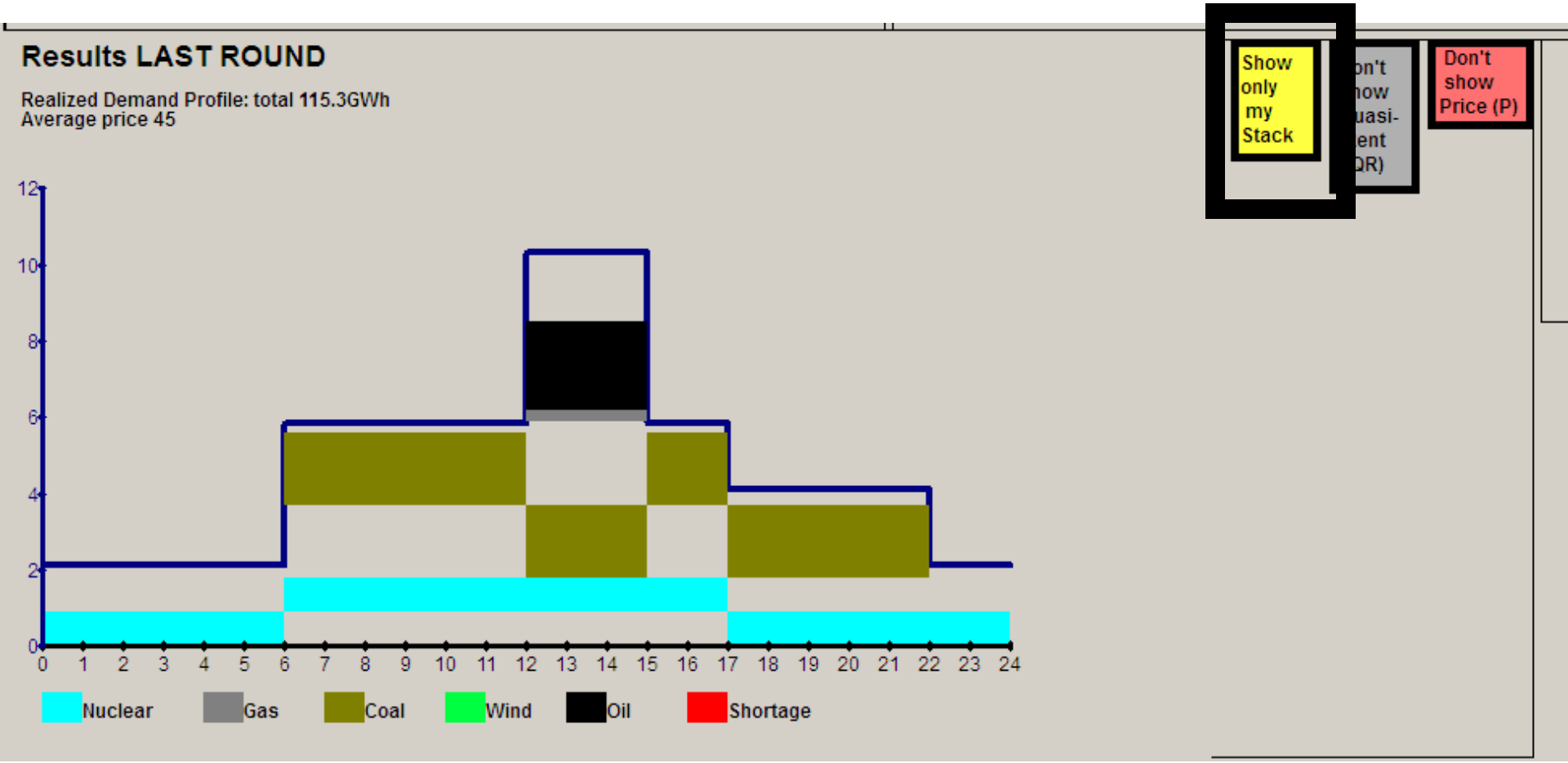
18 of 24 - Clipboard
Item collected.

Duopoly treatment



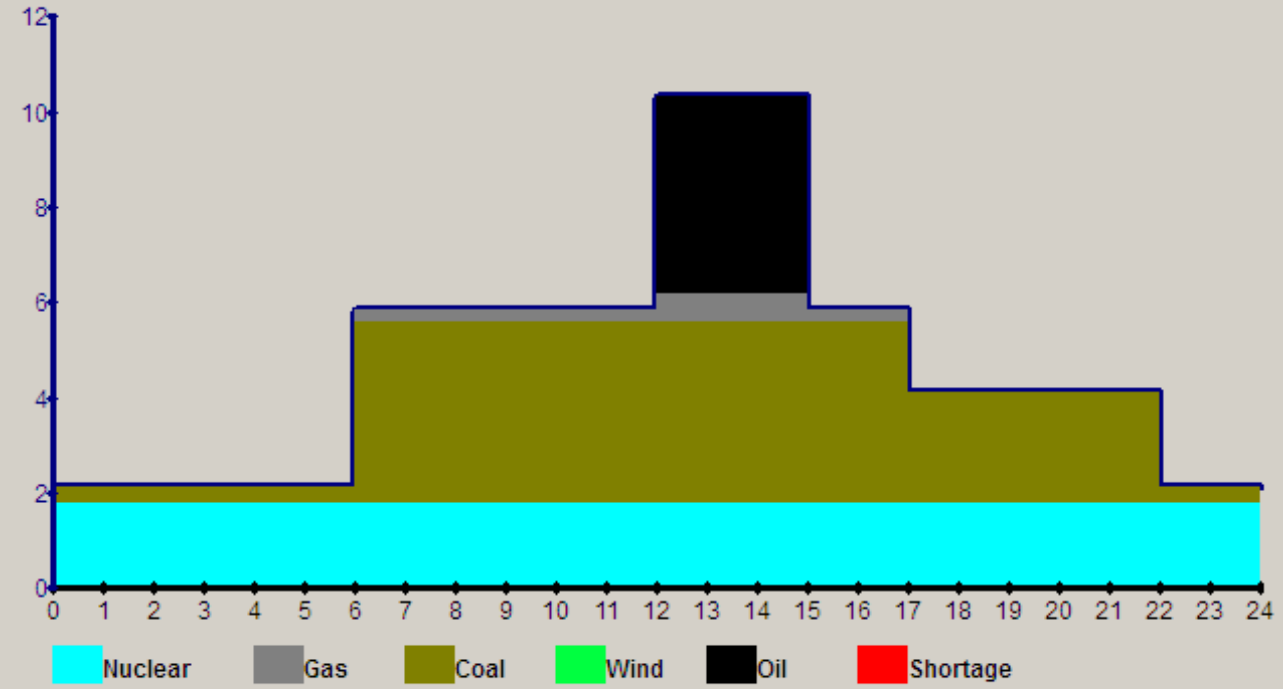
Period	Predicted Demand (GW)	Realized Demand (GW)	Nuclear Installed	Gas Installed	Coal Installed	Wind Installed	Oil Installed	Nuclear Bid	Gas Bid	Coal Bid	Wind Bid	Wind Availability (%)	Oil Bid	Profit	TotalProfit	WINNER	WINNER PROFIT
---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
1	114.0	115.3	0.9	0.3	1.9	0.0	2.3	3	40	30	1	20	70	-158	-158	1	-158

Duopoly treatment



Results PRESENT ROUND

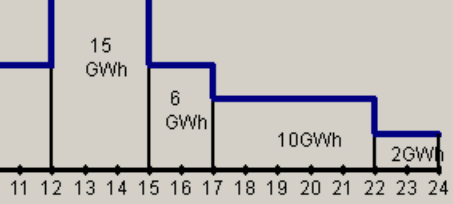
Realized Demand Profile: total 115.3GWh



Show Full Stack

Don't show Quasi-Rent (QR)

Don't show Price (P)



750	3	Nuclear	675	0.9	-	+
200	40	Gas	80	0.4	-	+
300	30	Coal	510	1.7	-	+
300	1	Wind (20%)	0	0.0	-	+
10	70	Oil	21	2.1	-	+

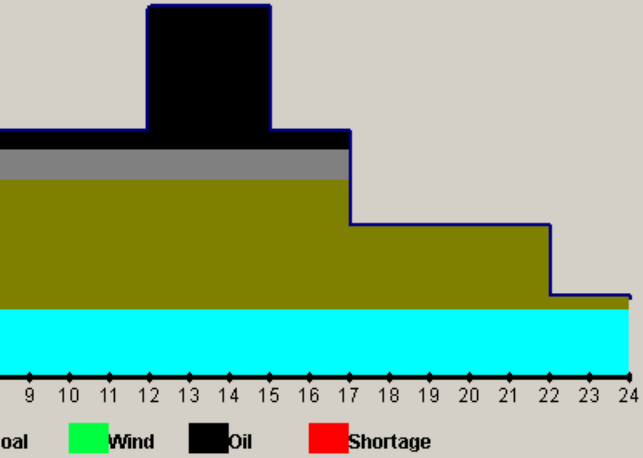
TOTAL INSTALLED GENERATION CAPACITY 5.1

Nuclear	3
Gas	40
Coal	30
Wind	1
Oil	70

Show only my Stack

Don't show Quasi-Rent (QR)

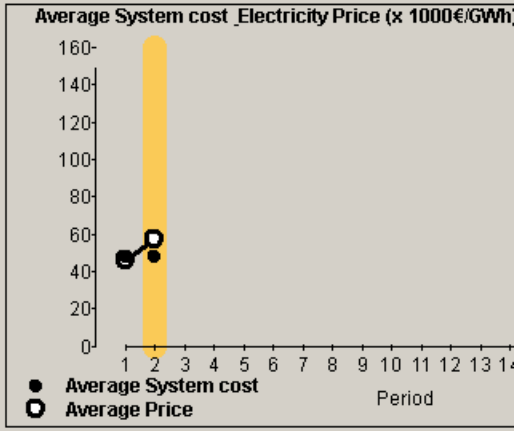
Don't show Price (P)



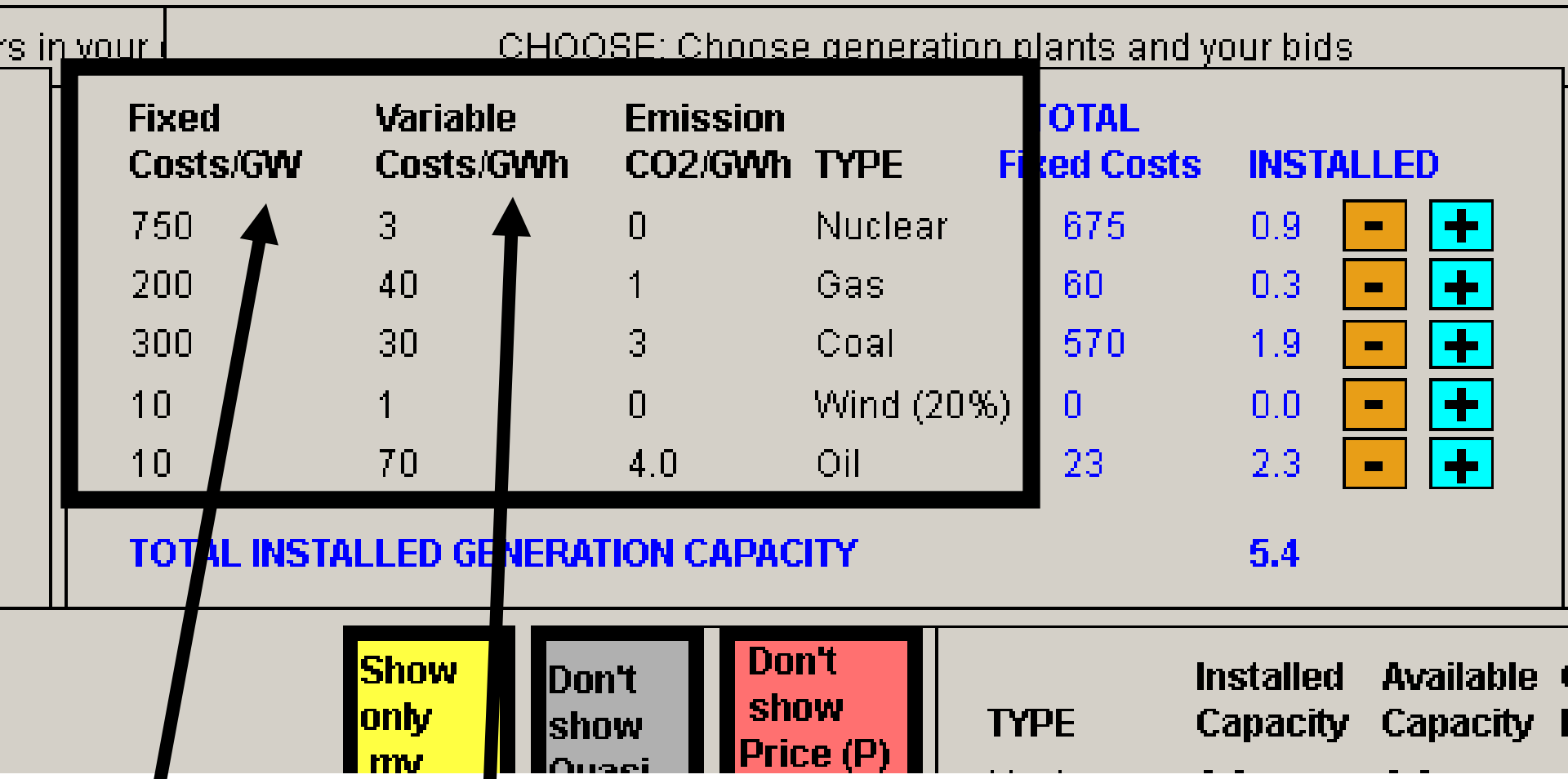
TYPE	Installed Capacity	Available Capacity	Capacity Factor	Profit	Emission CO2
Nuclear	0.9	0.9	1.00	**304**	0
Gas	0.4	0.4	0.46	**52**	4
Coal	1.7	1.7	0.62	**238**	76
Wind (20%)	0.0	0.0	0.00	**0**	0
Oil	2.1	2.1	0.15	**-21**	30
TOTAL PROFIT				**573**	111

The highest profit this round is by Subject no.1 with 1424

The lowest profit from all groups was 573
The average profit over all groups was 999



ized d (GW)	Nuclear Installed	Gas Installed	Coal Installed	Wind Installed	Oil Installed	Nuclear Bid	Gas Bid	Coal Bid	Wind Bid	Wind Availabillity (%)	Oil Bid	Profit	TotalP
---	---	---	---	---	---	---	---	---	---	---	---	---	---
.1	0.9	0.3	1.9	0.0	2.3	3	40	30	1	30	70	-62	-6
.1	0.9	0.4	1.7	0.0	2.1	3	40	30	1	30	70	573	51



Power

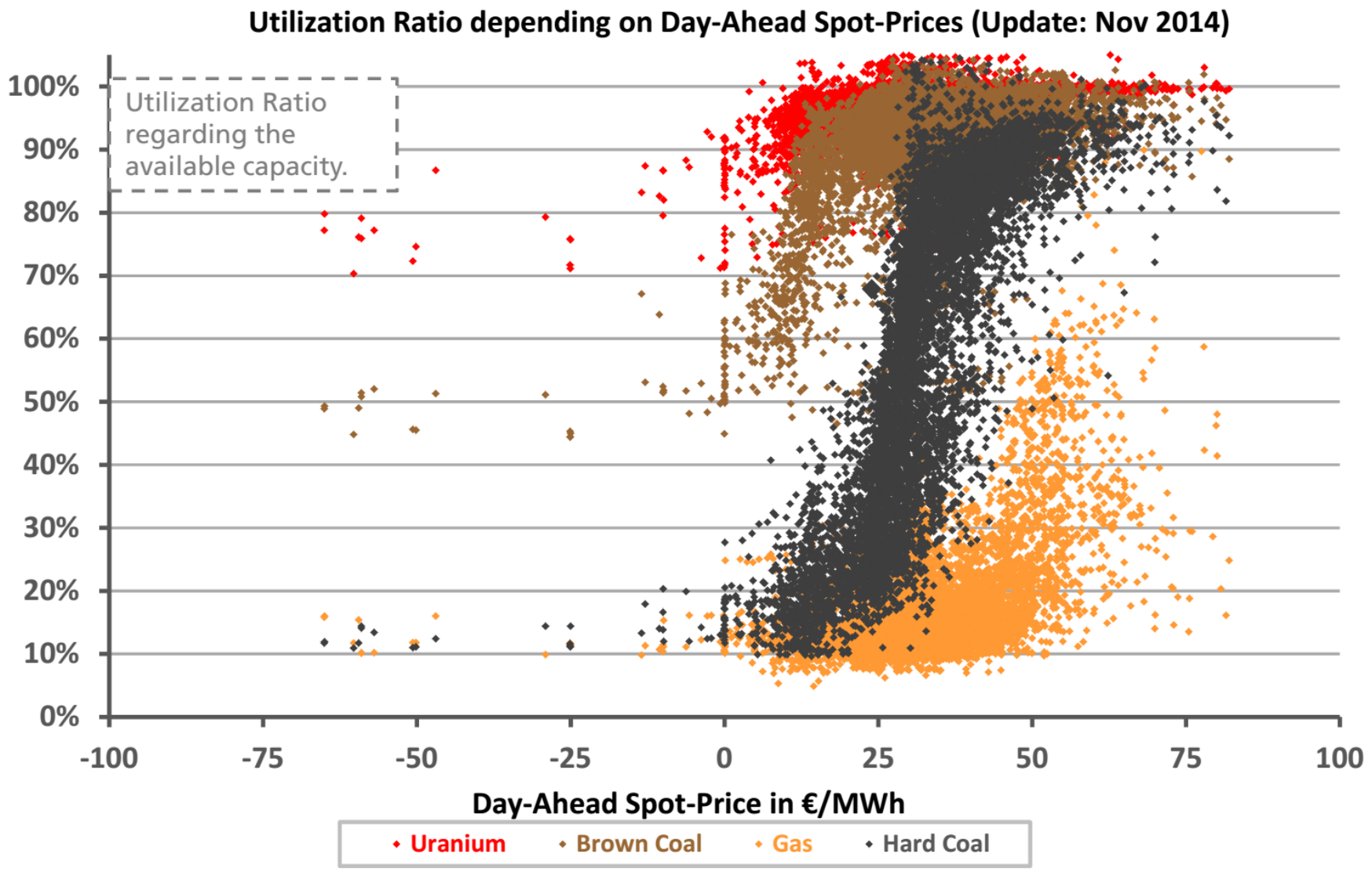
(Capacity)

Energy

For finding the cheapest technique it is useful to know the average cost…

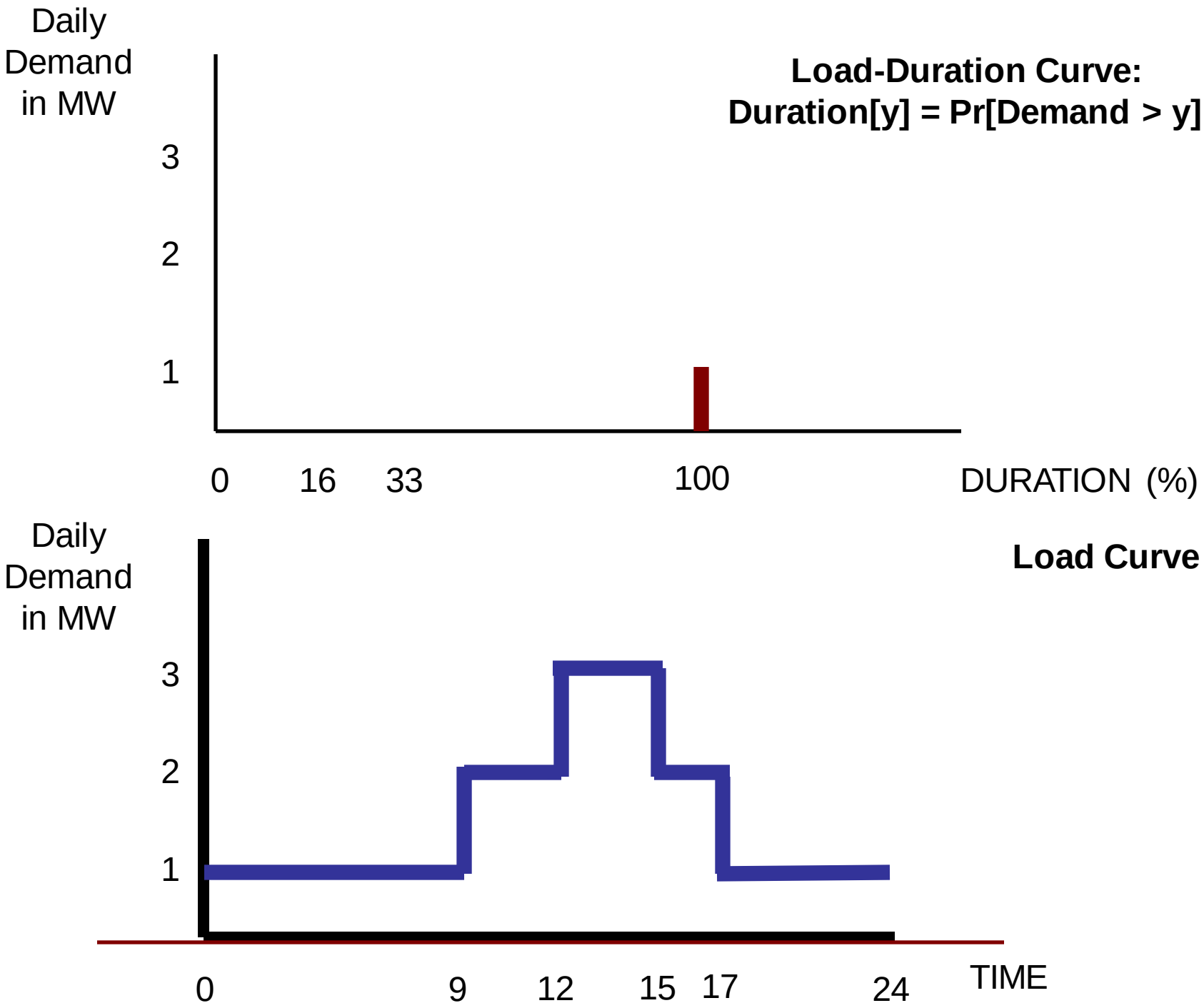
Fixed versus variable cost

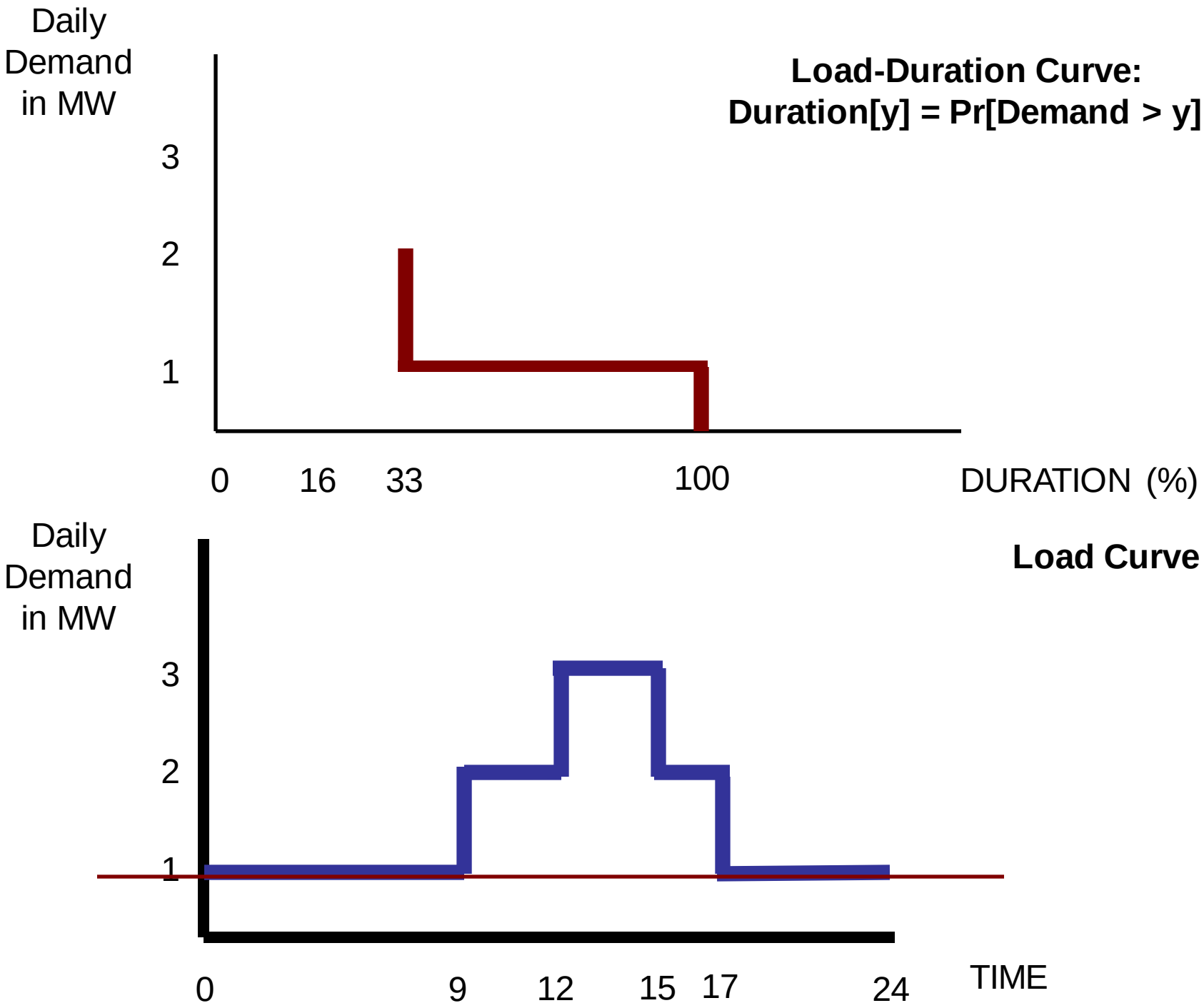
Plant System Utilization over Day-Ahead Prices

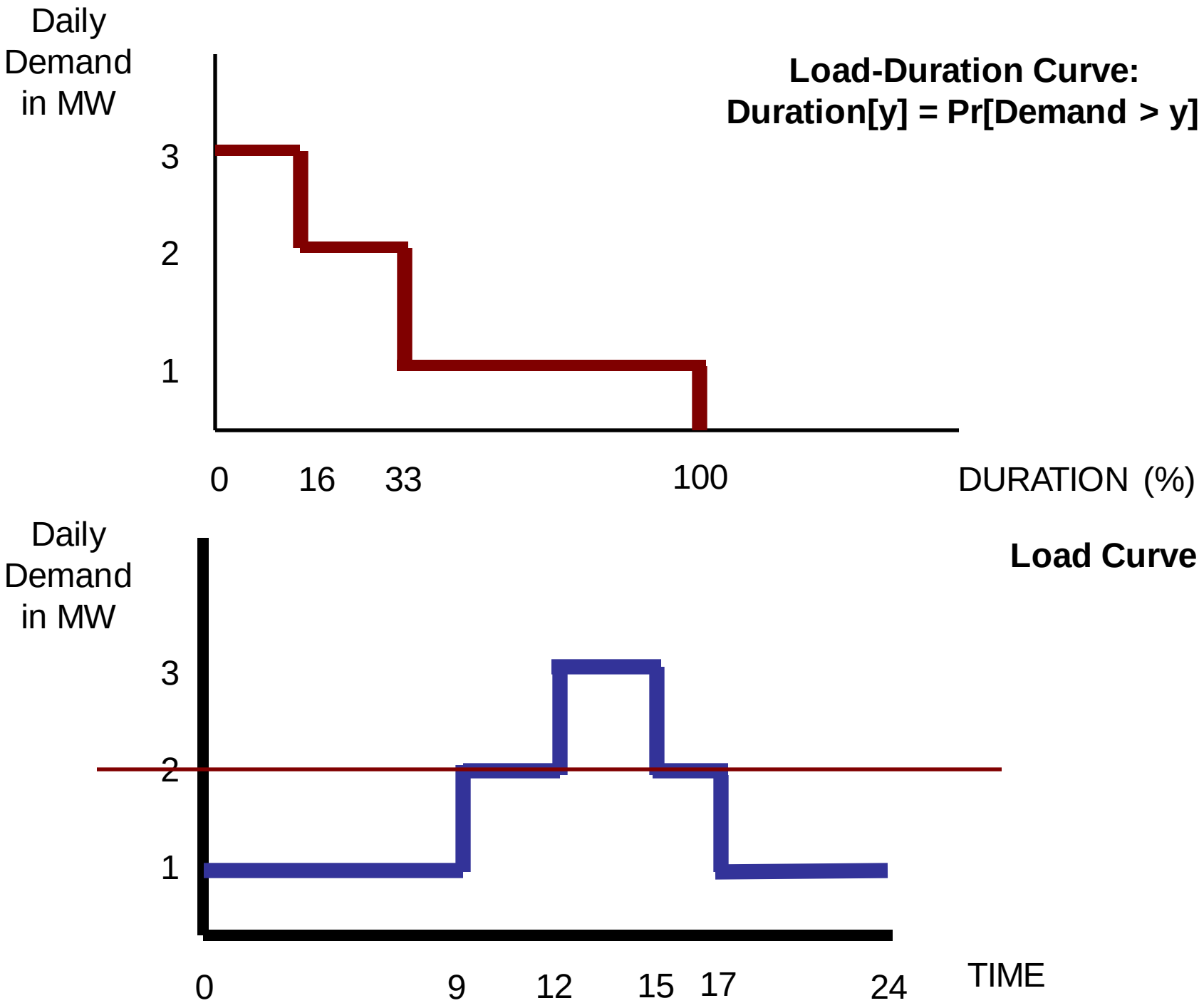


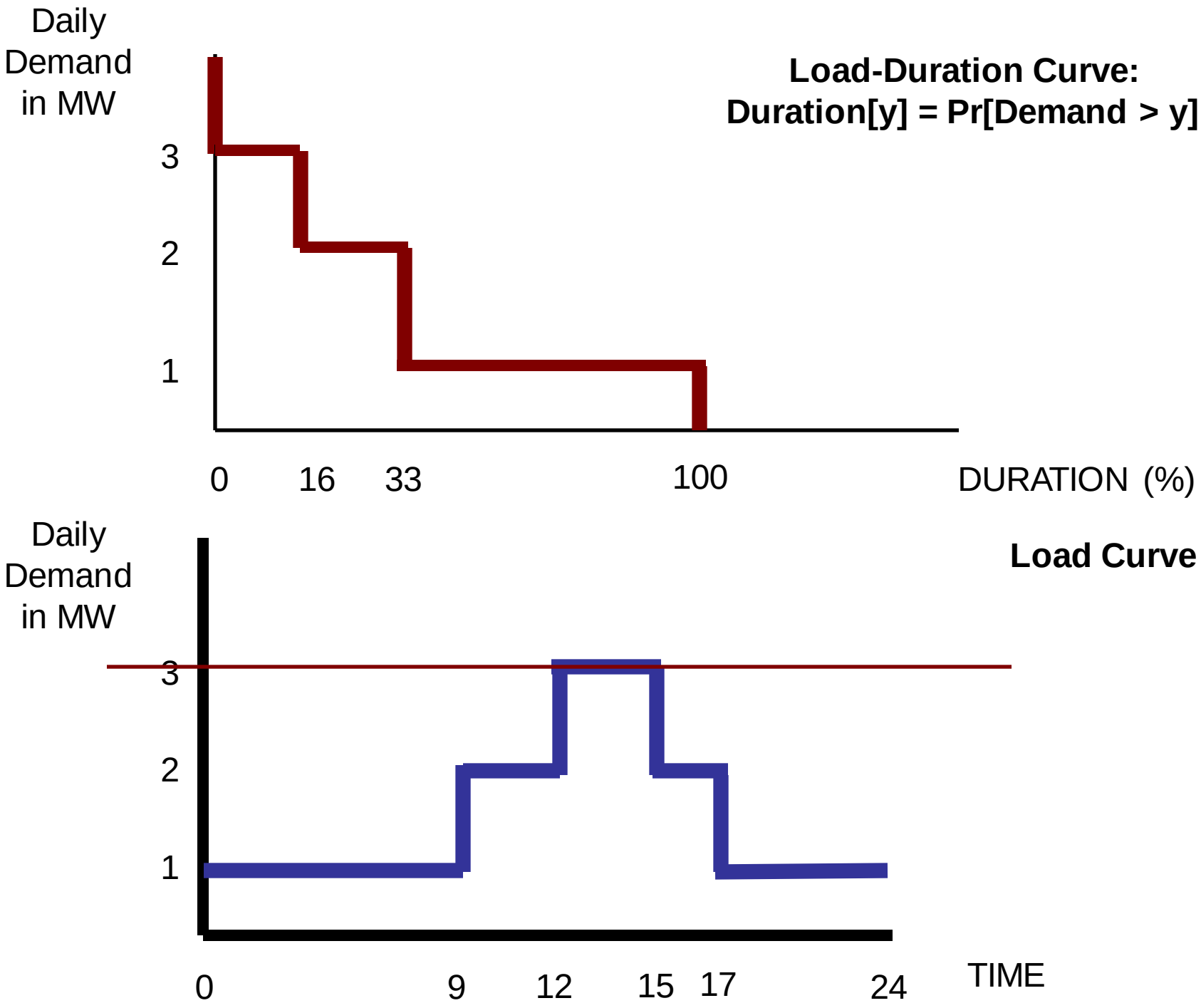
Source: Johannes Mayer; Fraunhofer ISE; Data: EPEX-SPOT / EEX, Destatis

Fraunhofer ISE

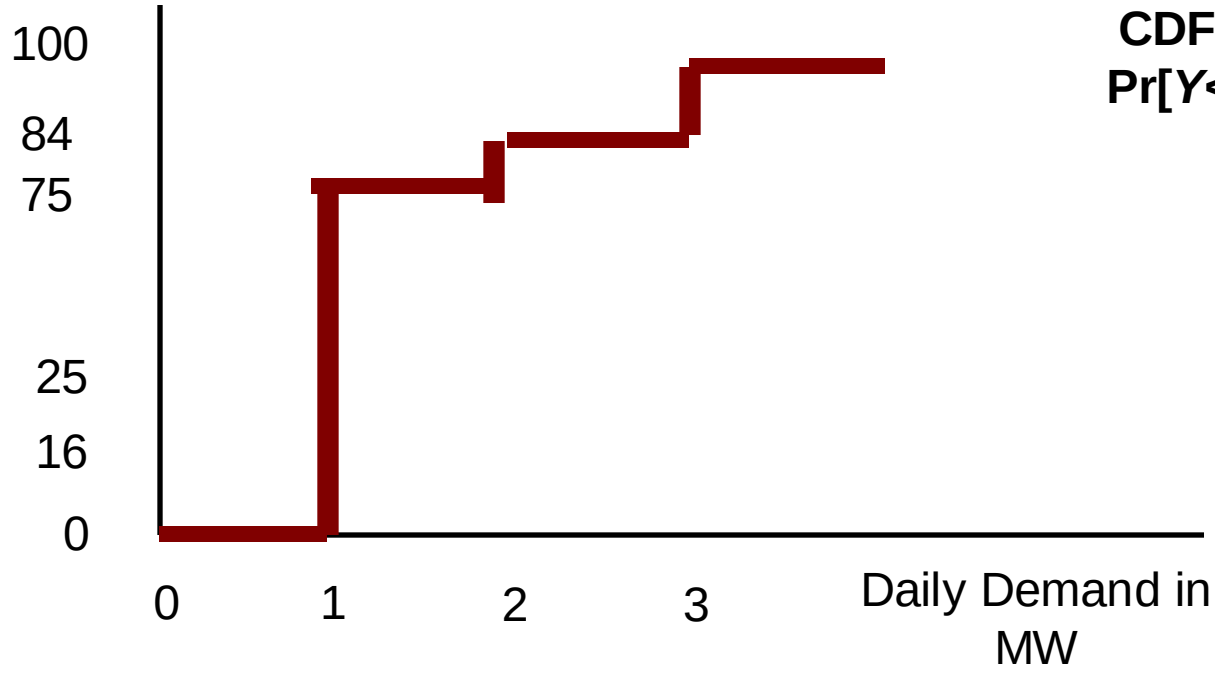

Daily
Demand
in MW
Load-Duration Curve:
Duration[y] = Pr[Demand > y]
3
2
1
0
16
33
100
DURATION (%)
Daily
Demand
in MW
Load Curve
3
2
1
0
9
12
15
17
24
TIME

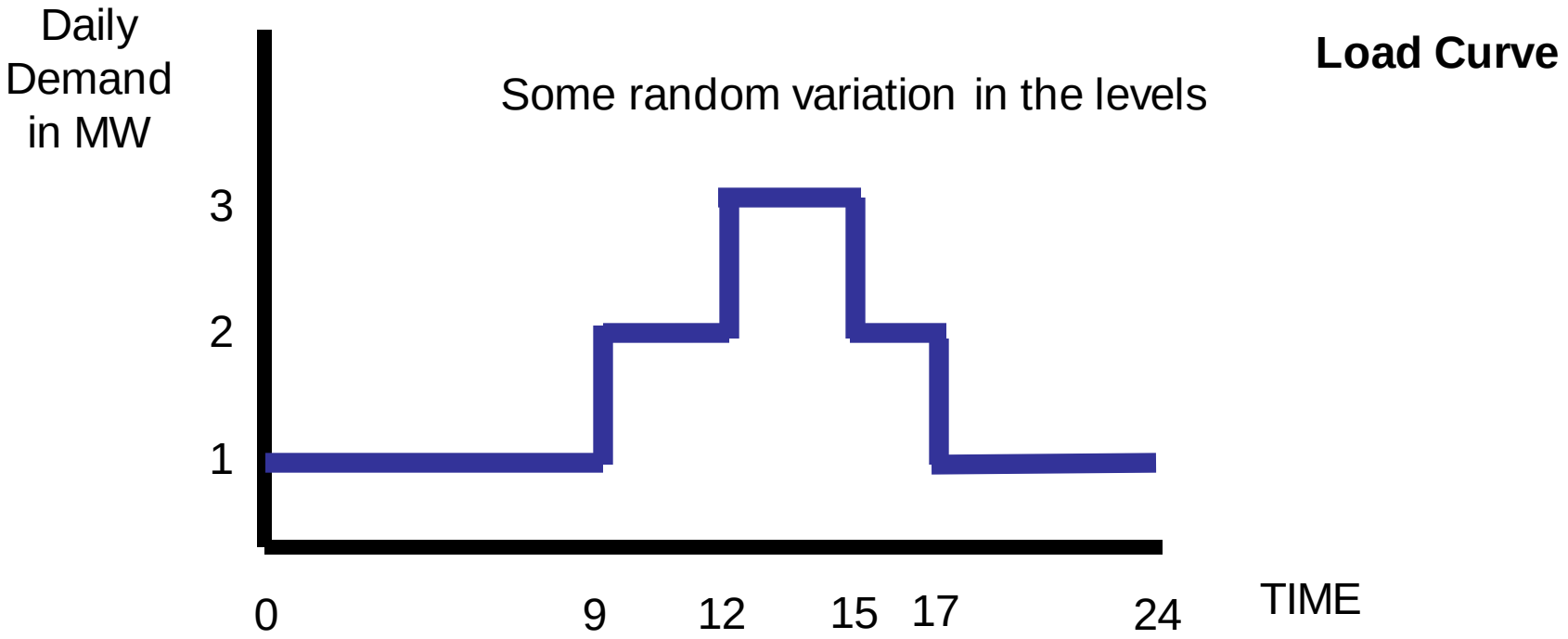

Daily
Demand
in MW
Load-Duration Curve:
Duration[y] = Pr[Demand > y]
3
2
1
0
16
33
100
DURATION (%)
Daily
Demand
in MW
Load Curve
3
2
1
0
9
12
15
17
24
TIME

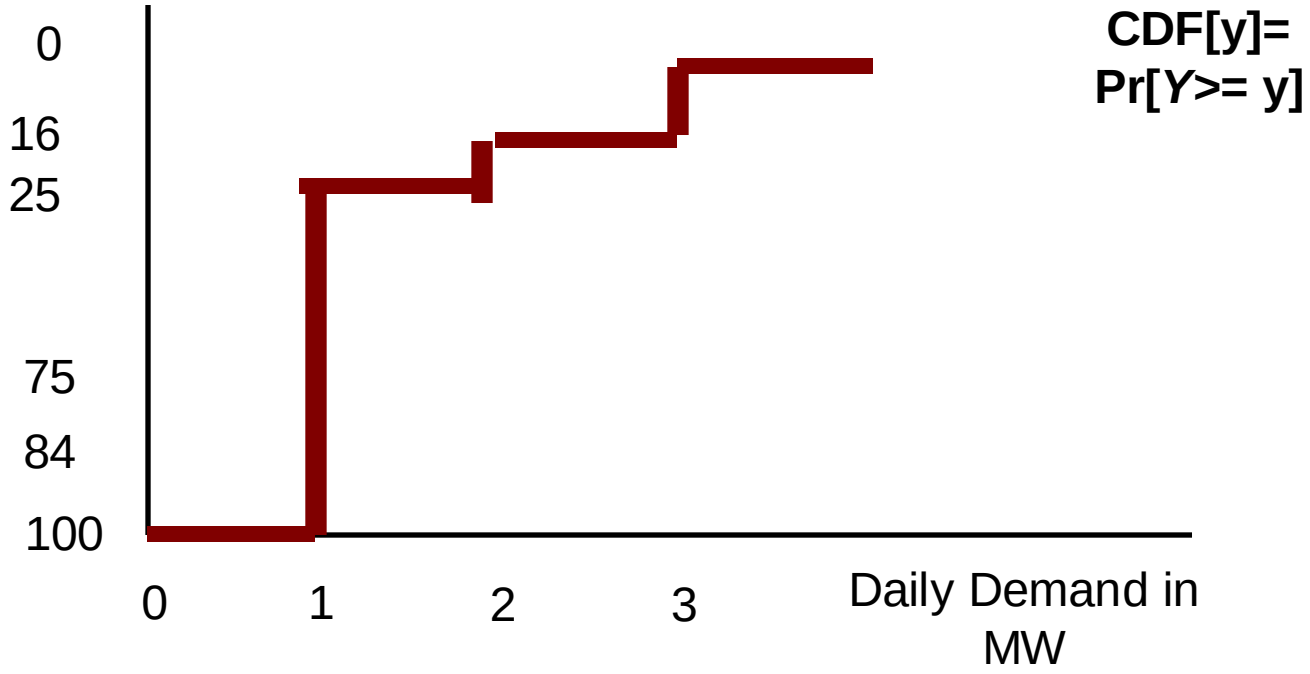

Daily
Demand
in MW
Load-Duration Curve:
Duration[y] = Pr[Demand > y]
3
2
1
0
16
33
100
DURATION (%)
Daily
Demand
in MW
Load Curve
3
2
1
0
9
12
15
17
24
TIME

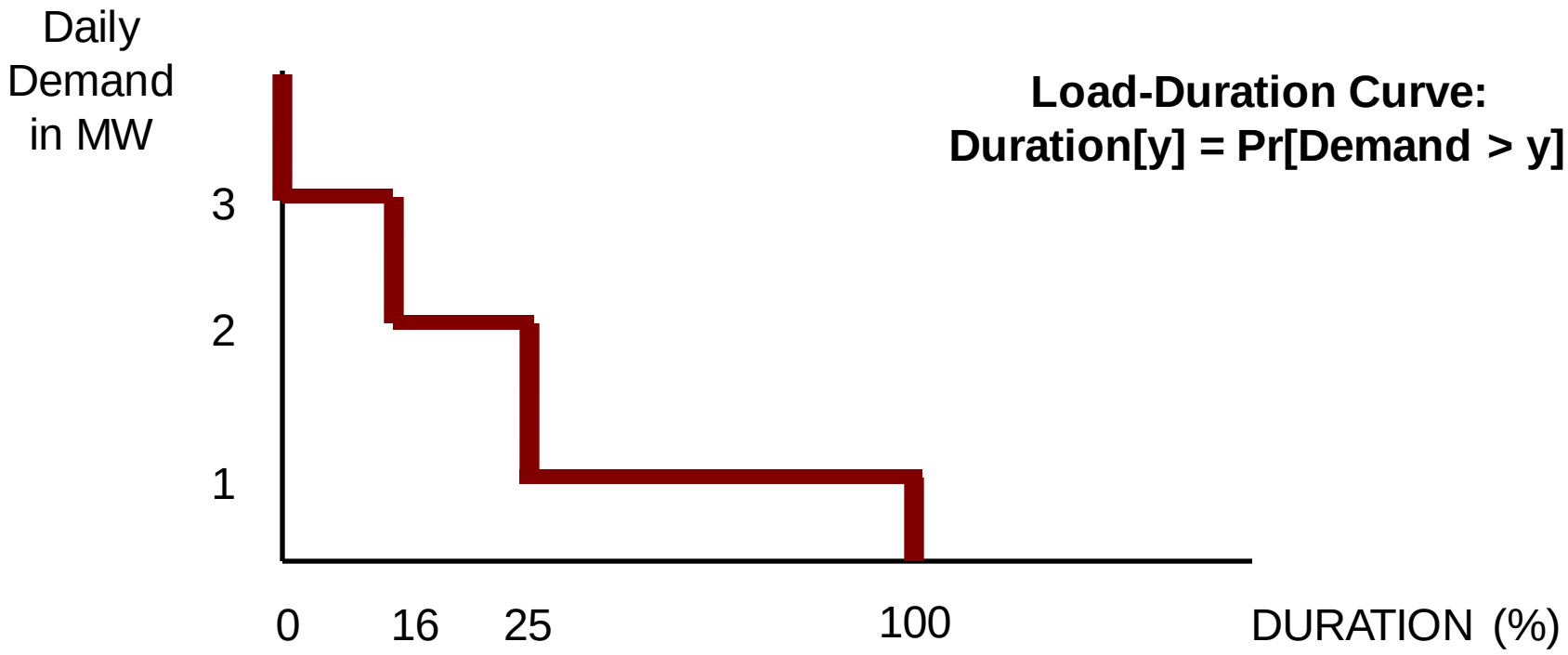

Daily
Demand
in MW
Load-Duration Curve:
Duration[y] = Pr[Demand > y]
3
2
1
0
16
33
100
DURATION (%)
Daily
Demand
in MW
Load Curve
3
2
1
0
9
12
15
17
24
TIME

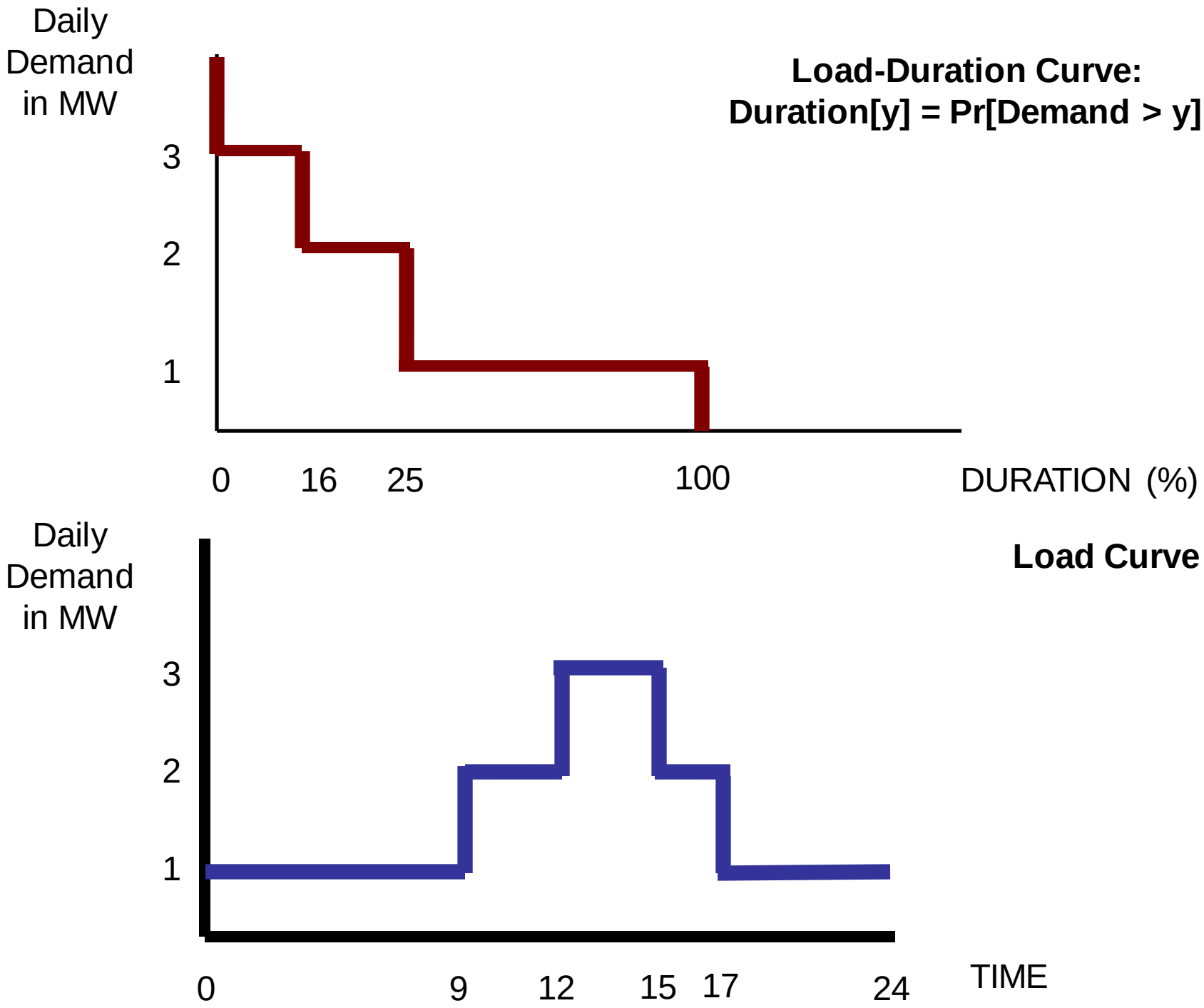
CDF

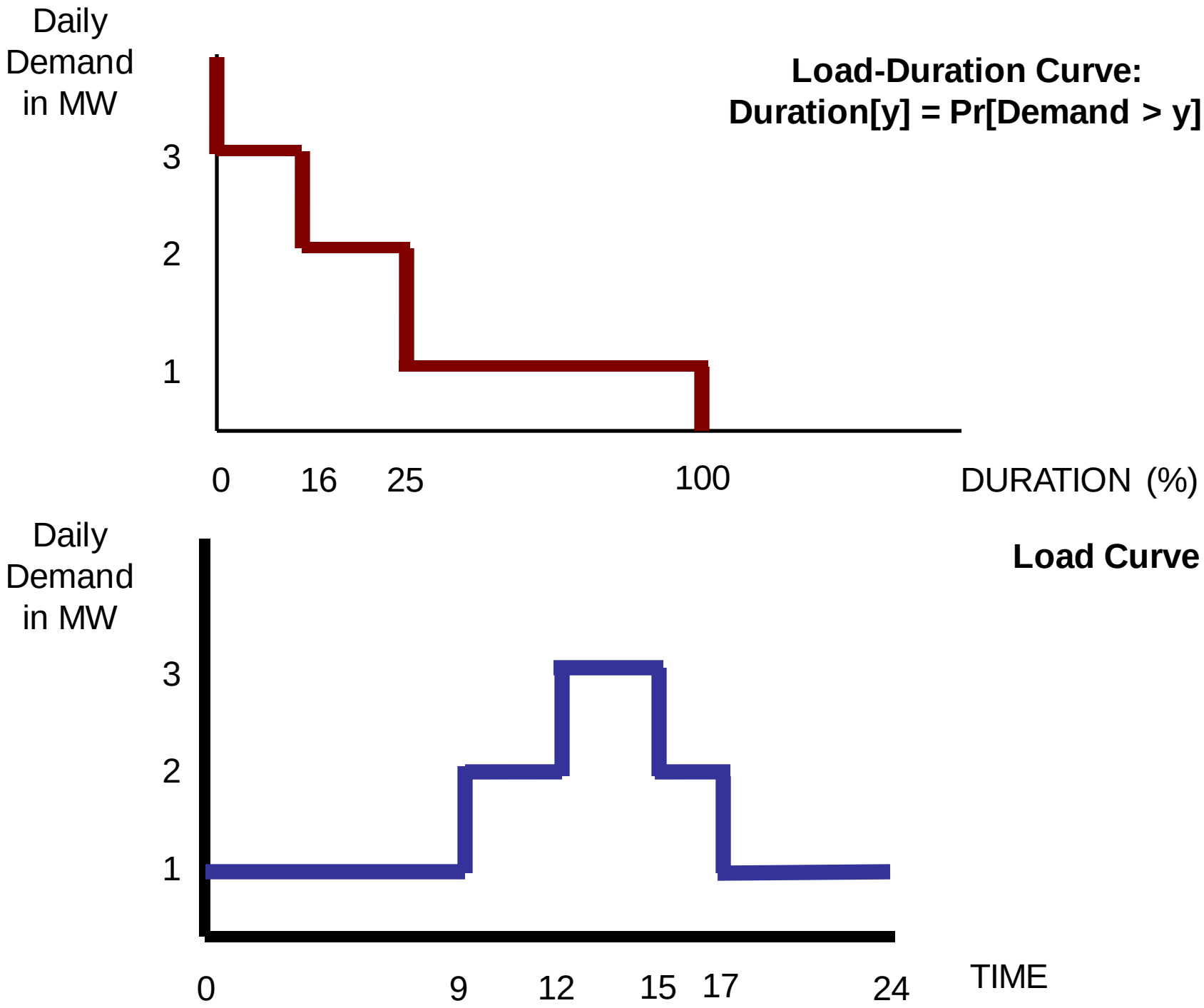

100
84
75
25
16
0
0
1
2
3
Daily Demand in MW
CDF[y]=
Pr[Y<= y]

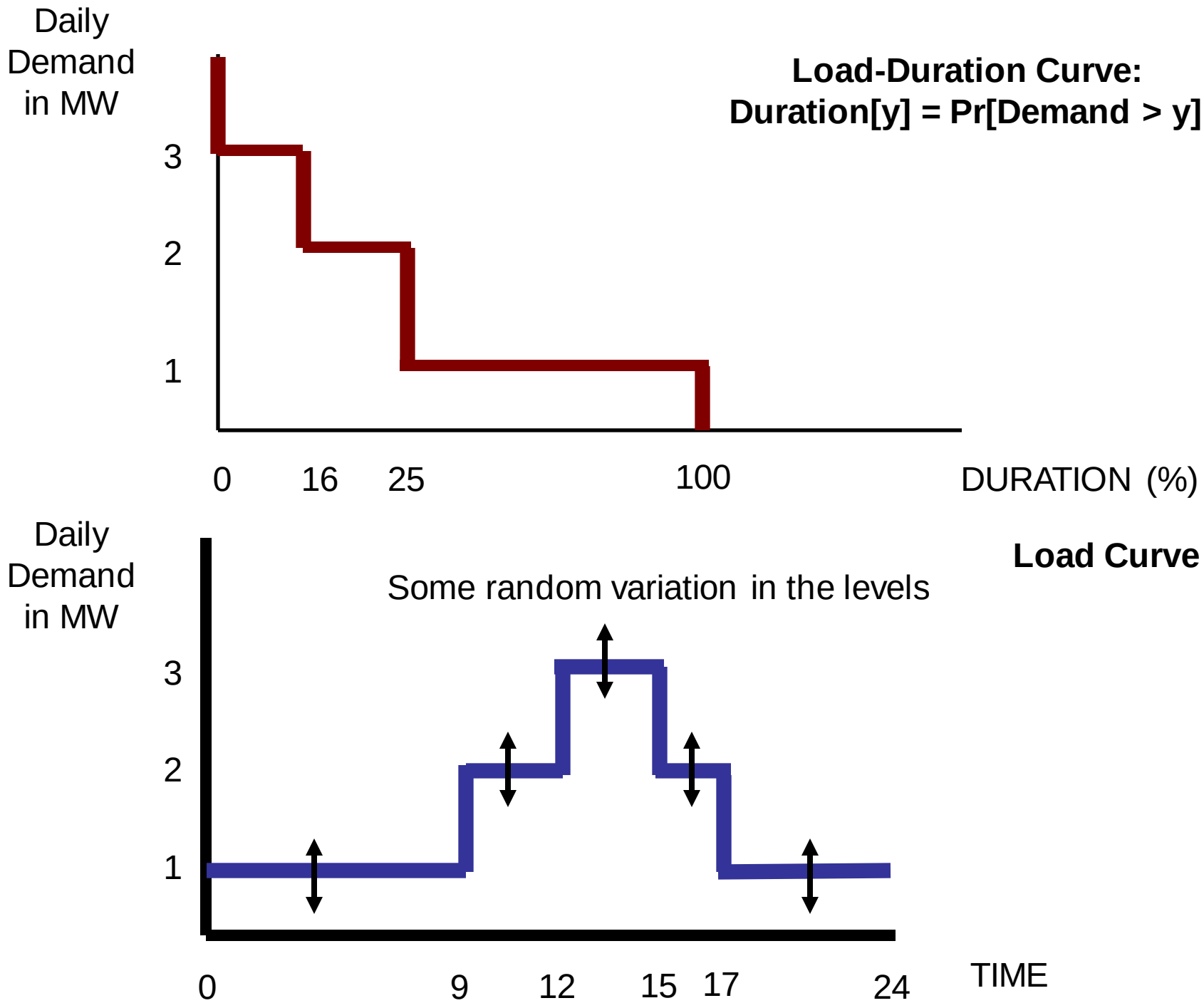

Daily Demand in MW
Some random variation in the levels
Load Curve
3
2
1
0
9
12
15
17
24
TIME

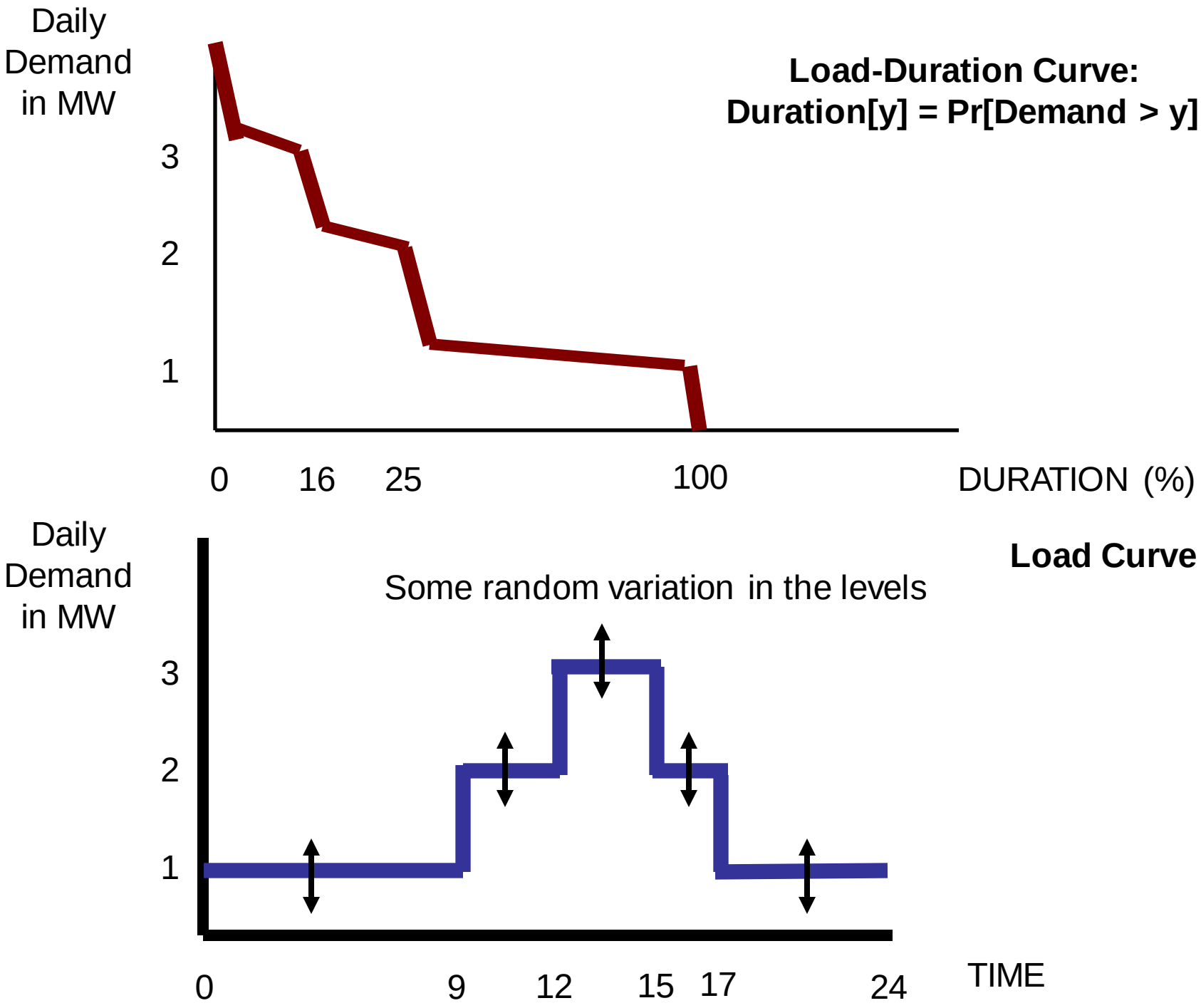

0
16
25
75
84
100
0
1
2
3
Daily Demand in MW
CDF[y]=
Pr[Y>= y]


Daily
Demand
in MW
Load-Duration Curve:
Duration[y] = Pr[Demand > y]
3
2
1
0
16
25
100
DURATION (%)

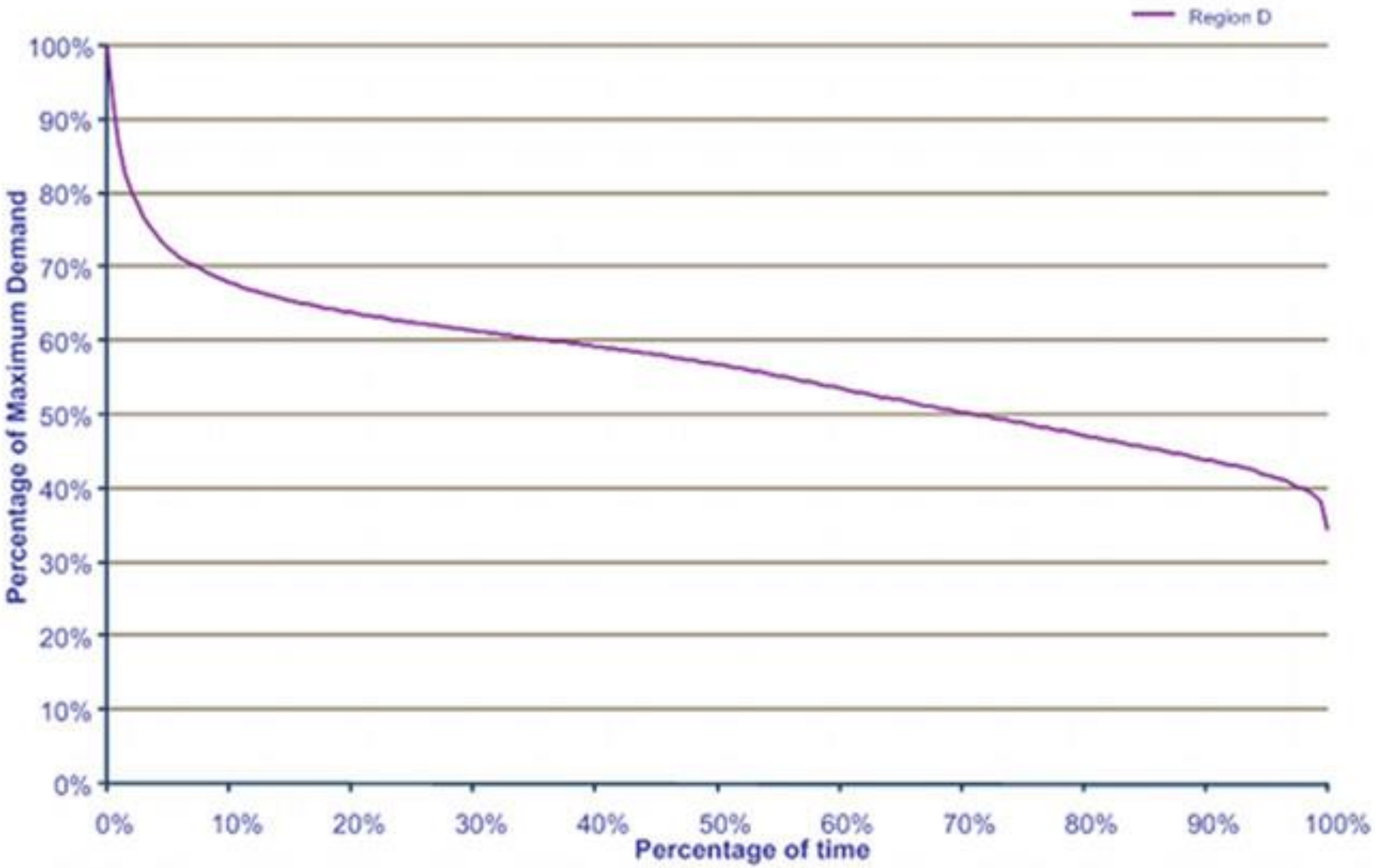

Daily
Demand
in MW
Load-Duration Curve:
Duration[y] = Pr[Demand > y]
3
2
1
0
16
25
100
DURATION (%)
Daily
Demand
in MW
Load Curve
3
2
1
0
9
12
15
17
24
TIME


Daily
Demand
in MW
Load-Duration Curve:
Duration[y] = Pr[Demand > y]
3
2
1
0
16
25
100
DURATION (%)
Daily
Demand
in MW
Load Curve
3
2
1
0
9
12
15
17
24
TIME

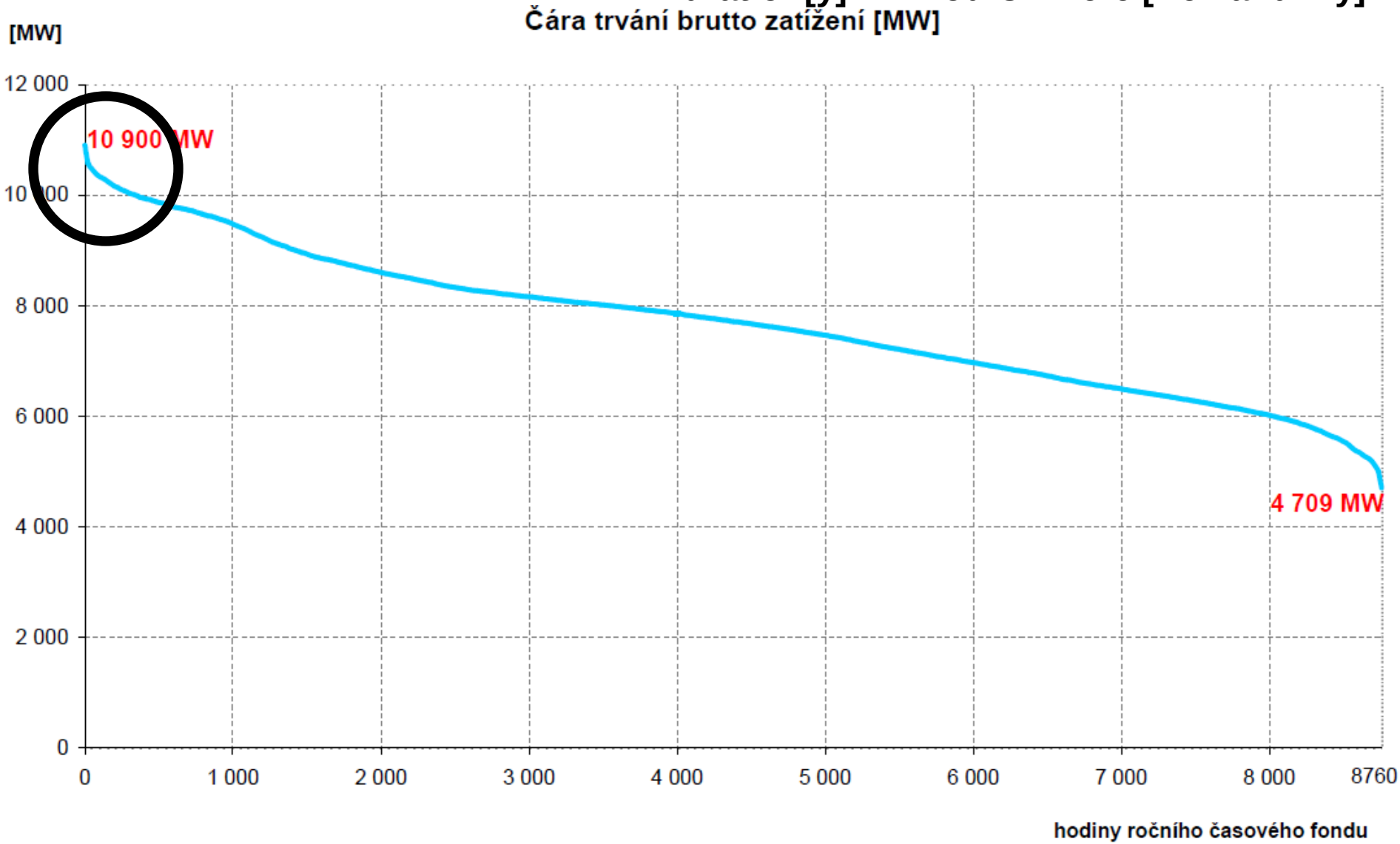

Daily
Demand
in MW
Load-Duration Curve:
Duration[y] = Pr[Demand > y]
3
2
1
0
16
25
100
DURATION (%)
Daily
Demand
in MW
Load Curve
Some random variation in the levels
3
2
1
0
9
12
15
17
24
TIME


Daily
Demand
in MW
3
2
1
0
16
25
100
DURATION (%)
Load-Duration Curve:
Duration[y] = Pr[Demand > y]
Daily
Demand
in MW
Some random variation in the levels
Load Curve
3
2
1
0
9
12
15
17
24
TIME

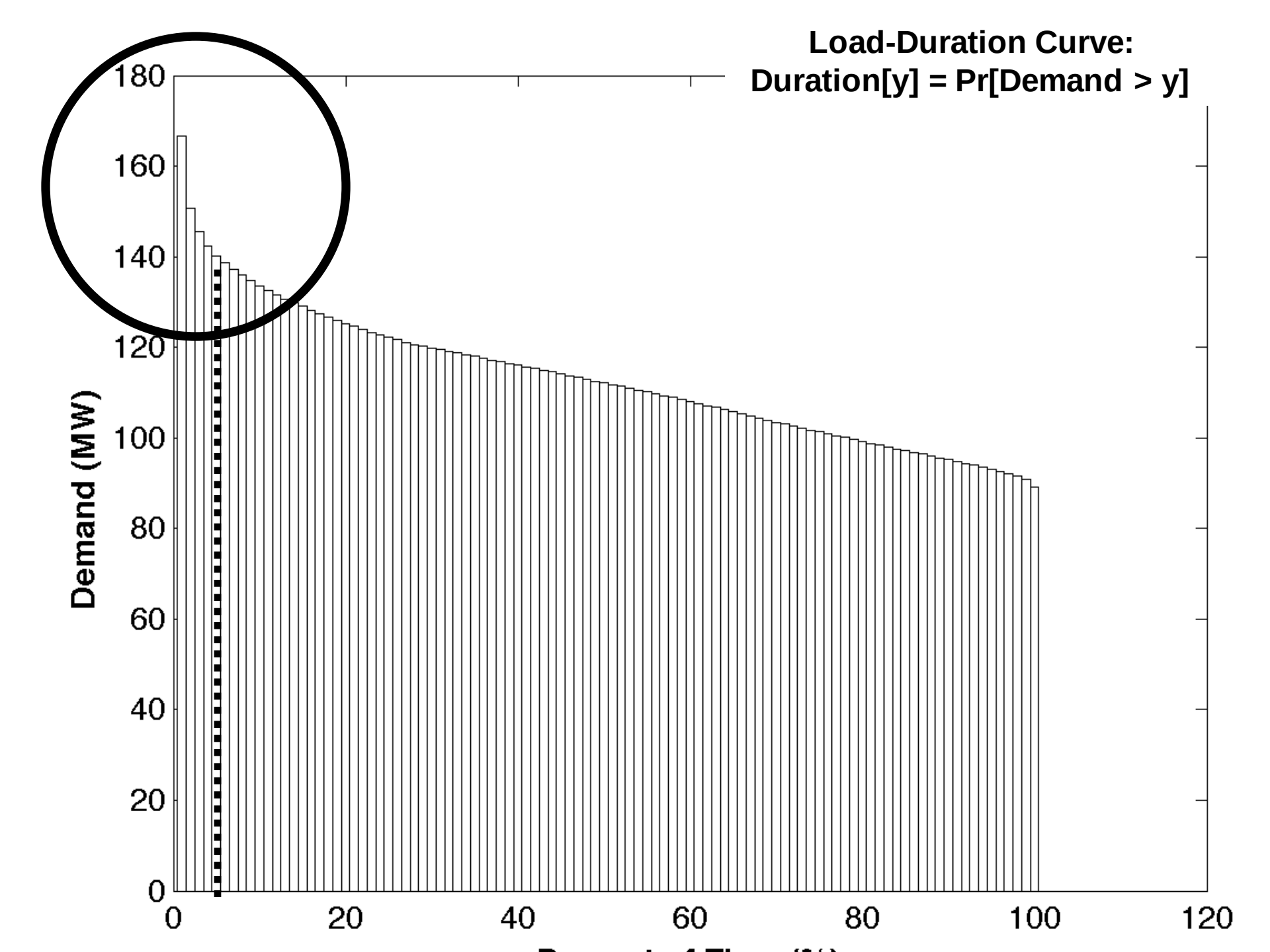
Load-Duration Curve:
Duration[y] = Pr[Demand > y]

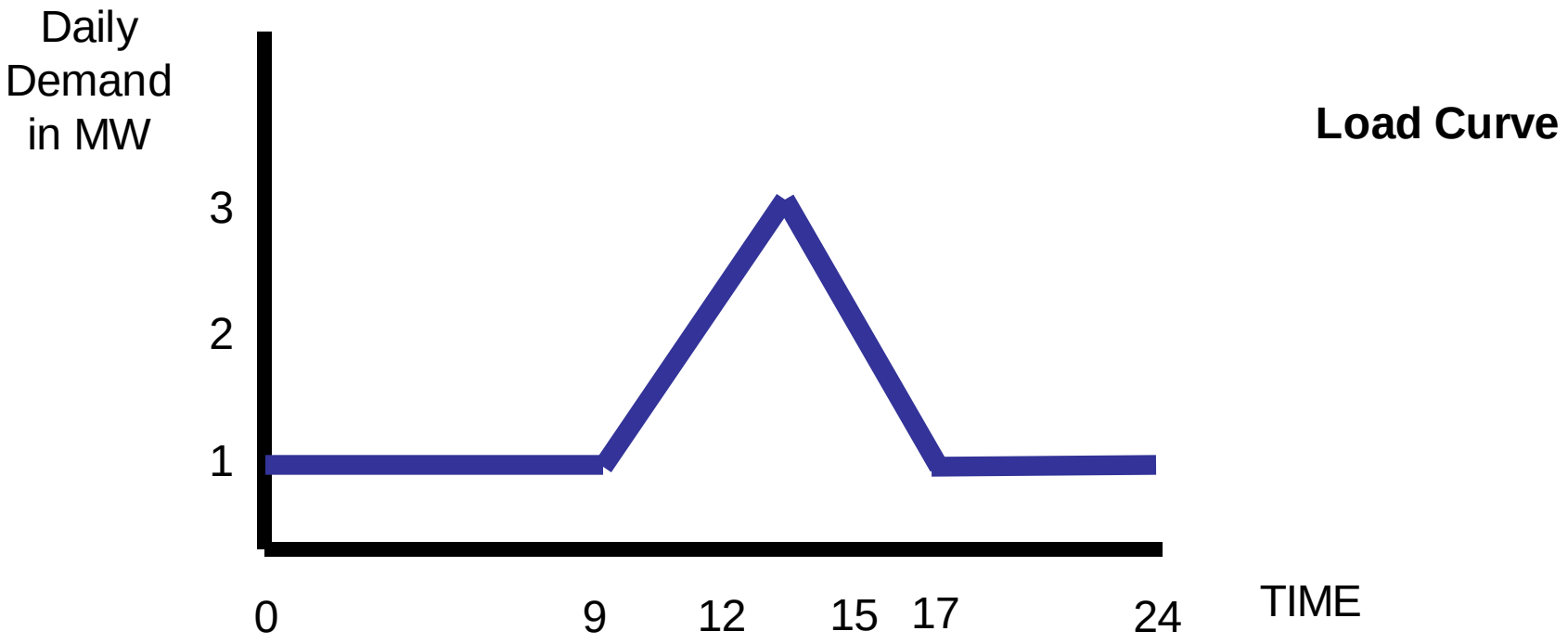


Load-Duration Curve:
Duration[y] = # Hours where [Demand > y]

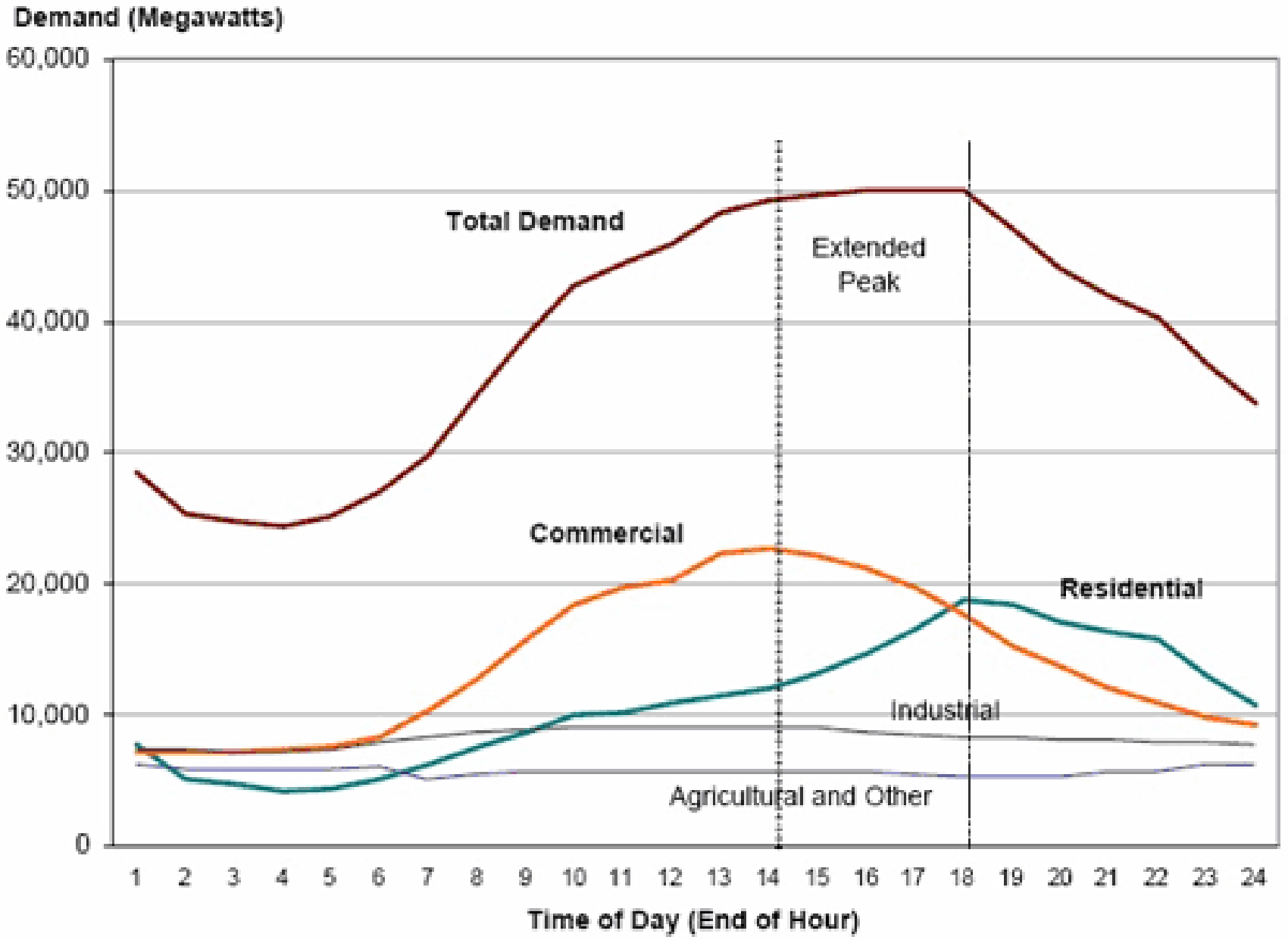


Source: ERU

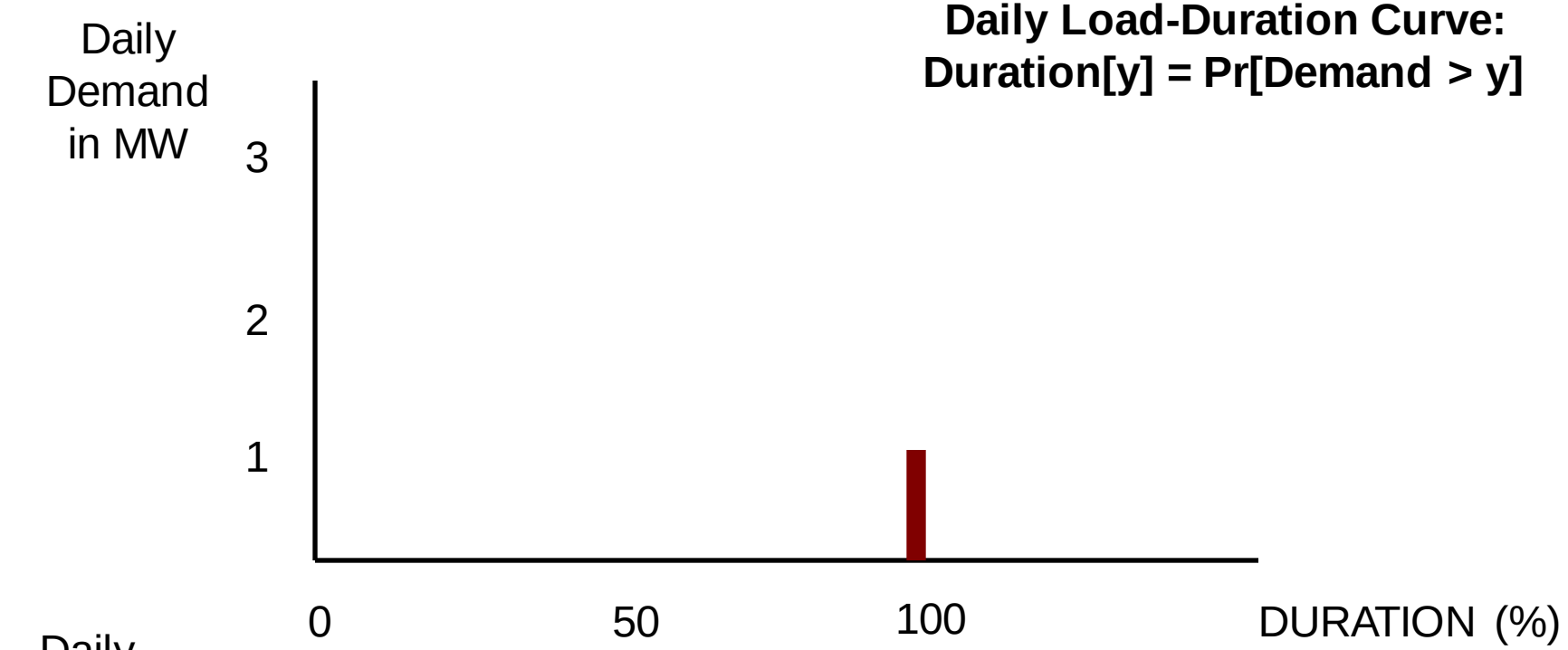

Load-Duration Curve:
Duration[y] = Pr[Demand > y]
Demand (MW)
180
160
140
120
100
80
60
40
20
0
0
20
40
60
80
100
120


Daily
Demand
in MW
3
2
1
0
9
12
15
17
24
TIME
Load Curve

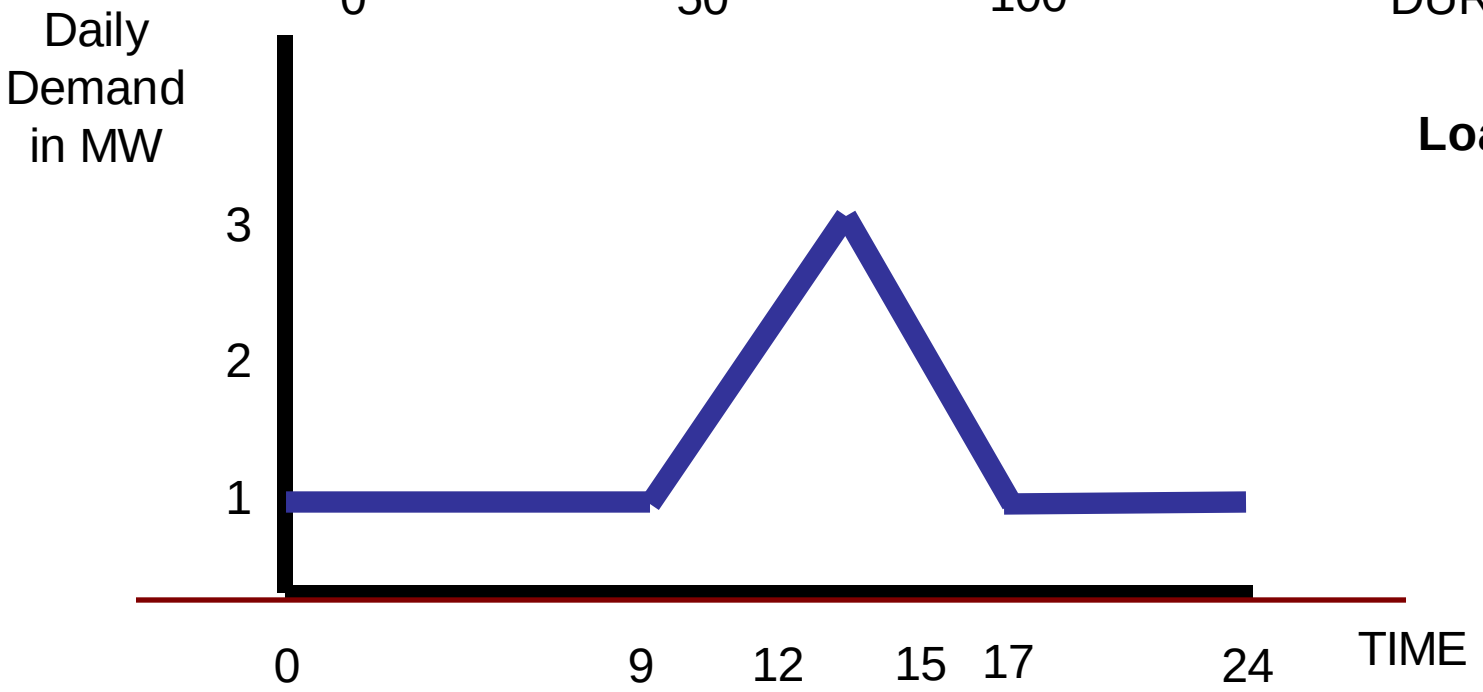
Daily variations (UK)

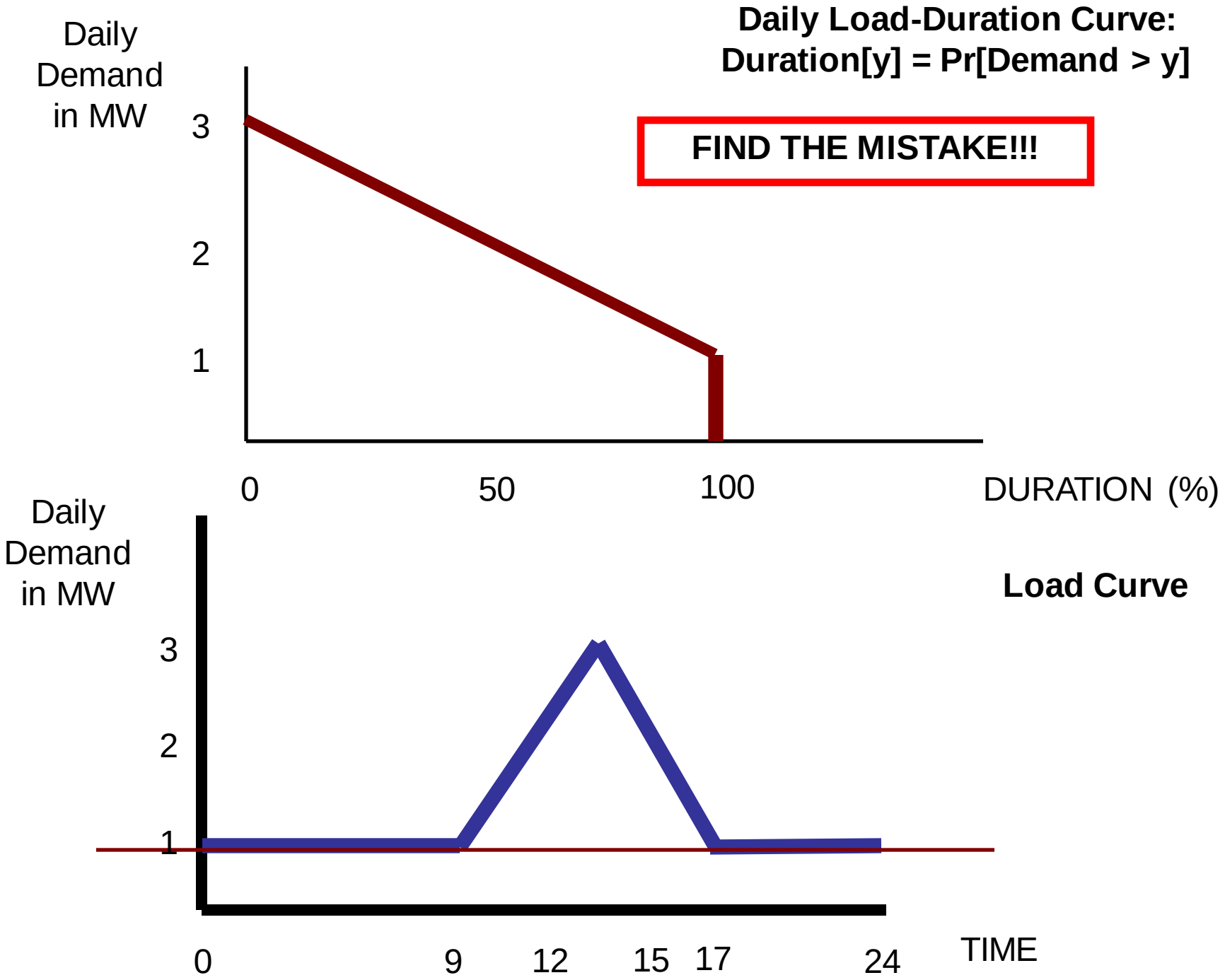


Daily Load-Duration Curve:
Duration[y] = Pr[Demand > y]

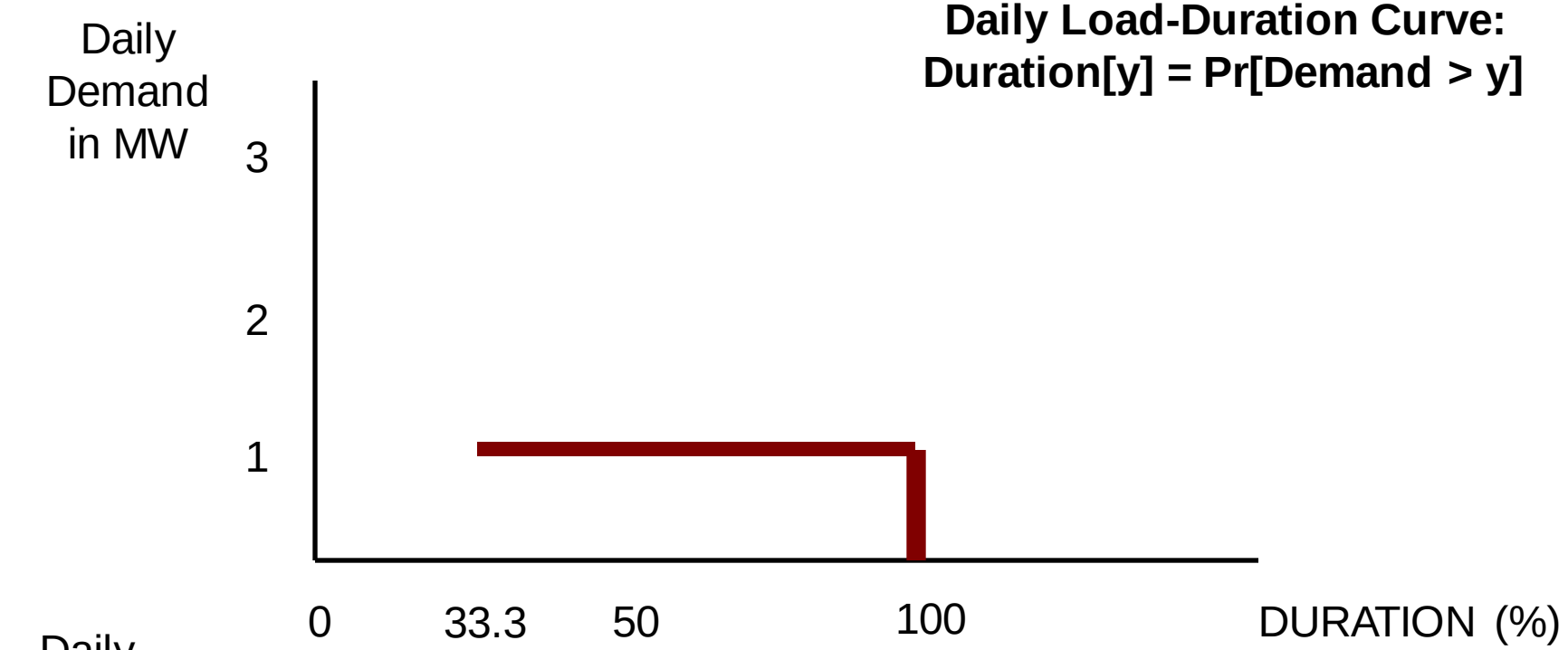


Load Curve

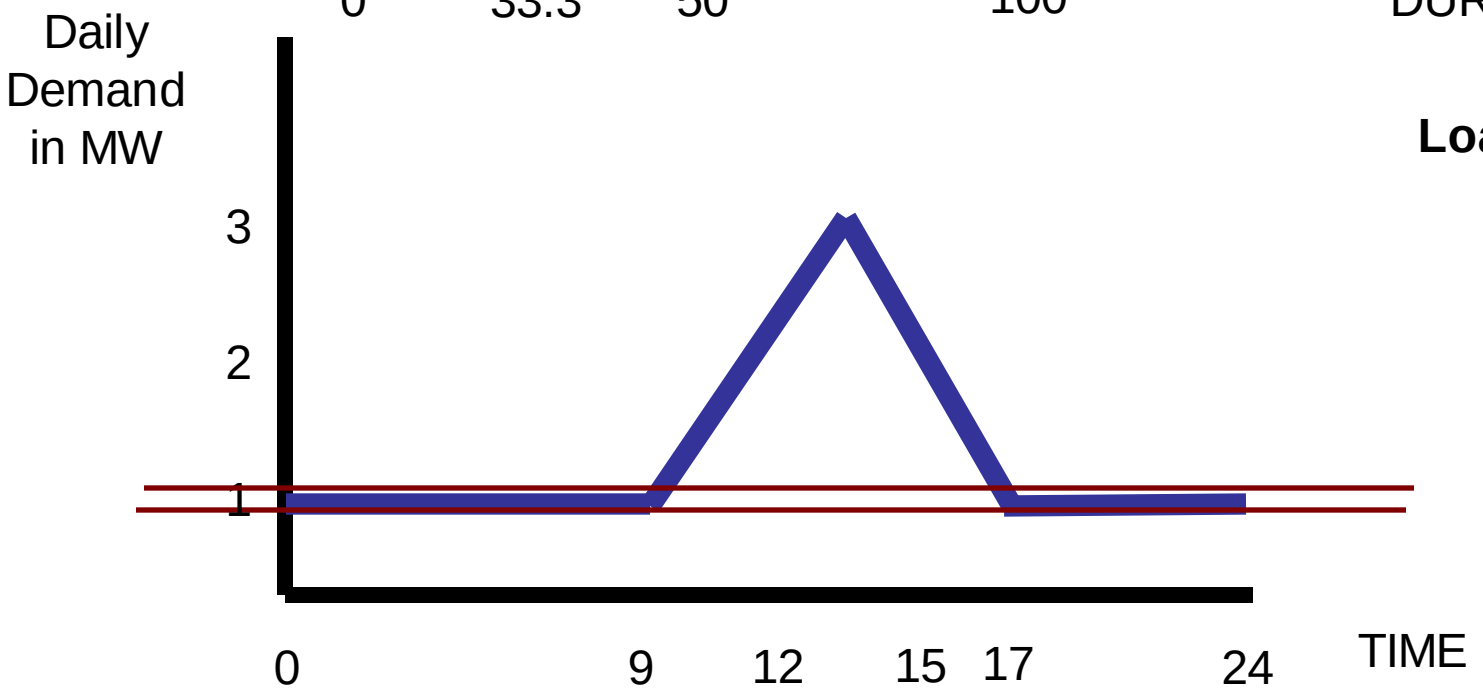


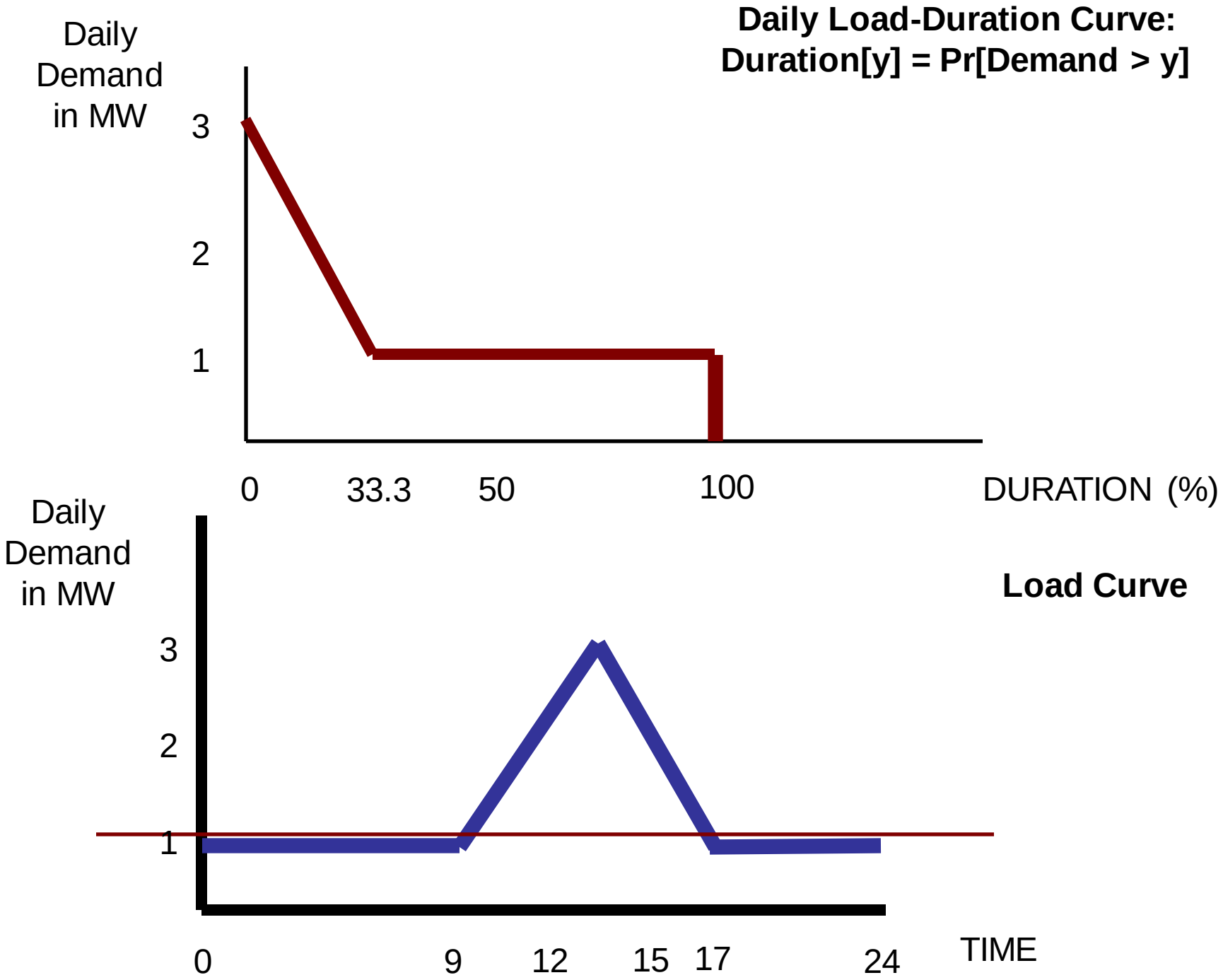

Daily Load-Duration Curve:
Duration[y] = Pr[Demand > y]
FIND THE MISTAKE!!!
Daily Demand in MW
3
2
1
0
50
100
DURATION (%)
Daily Demand in MW
Load Curve
3
2
1
0
9
12
15
17
24
TIME

Daily Load-Duration Curve:
Duration[y] = Pr[Demand > y]

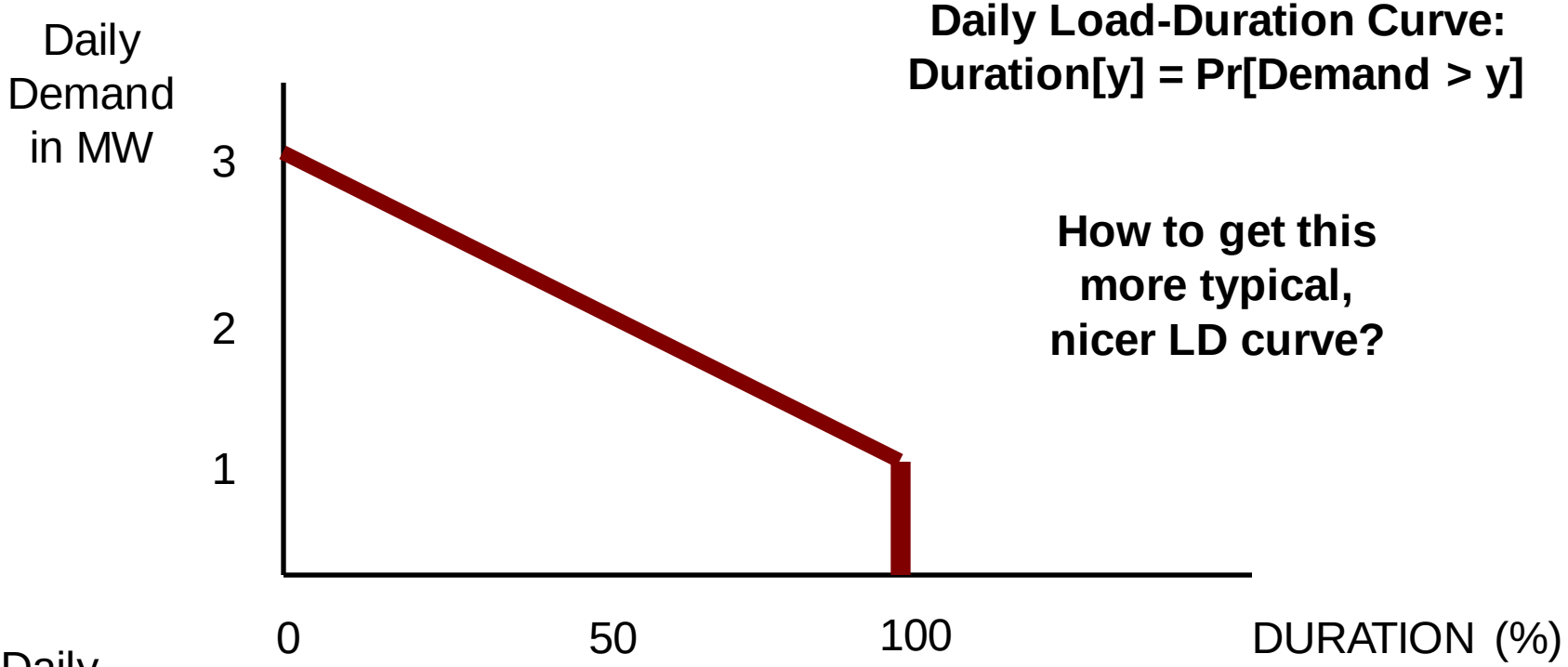


Load Curve

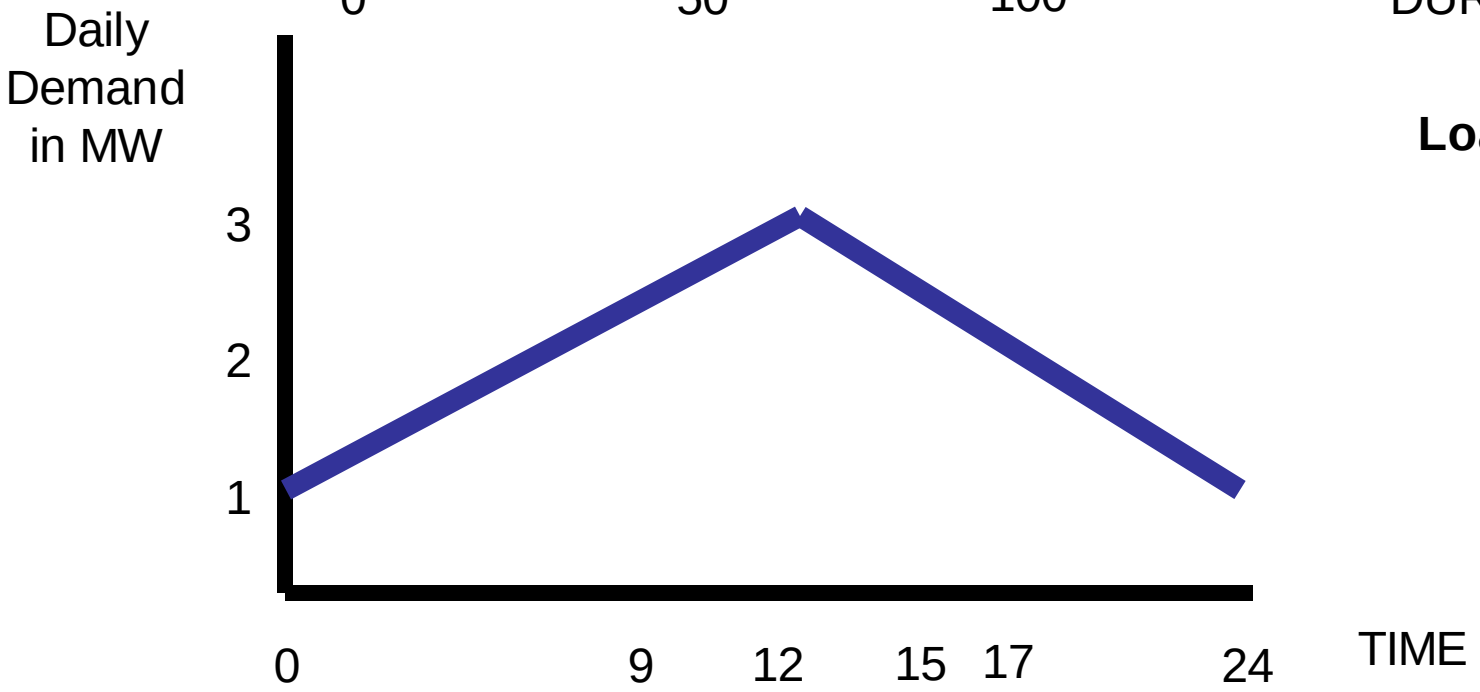



Daily Load-Duration Curve:
Duration[y] = Pr[Demand > y]
Daily Demand in MW
3
2
1
0
33.3
50
100
DURATION (%)
Daily Demand in MW
Load Curve
3
2
1
0
9
12
15
17
24
TIME

Daily Load-Duration Curve:
Duration[y] = Pr[Demand > y]

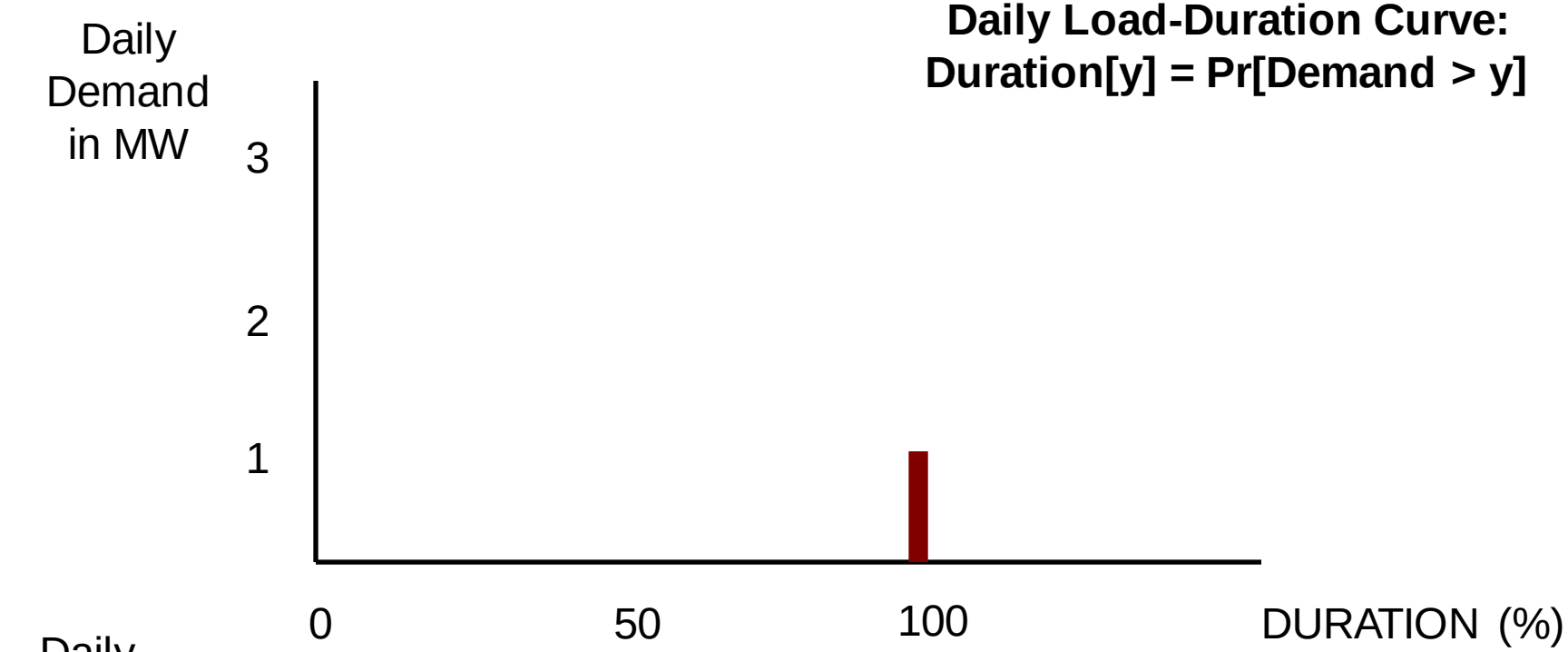


How to get this more typical, nicer LD curve?

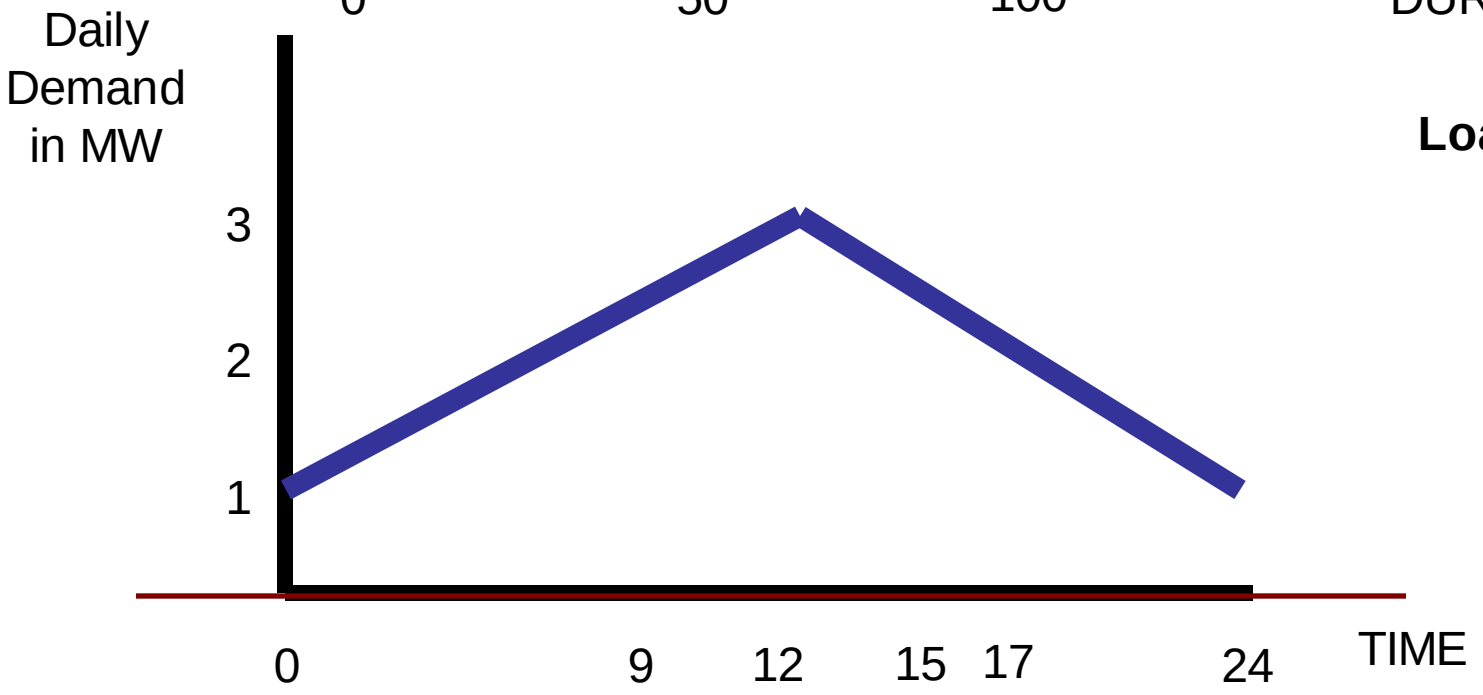


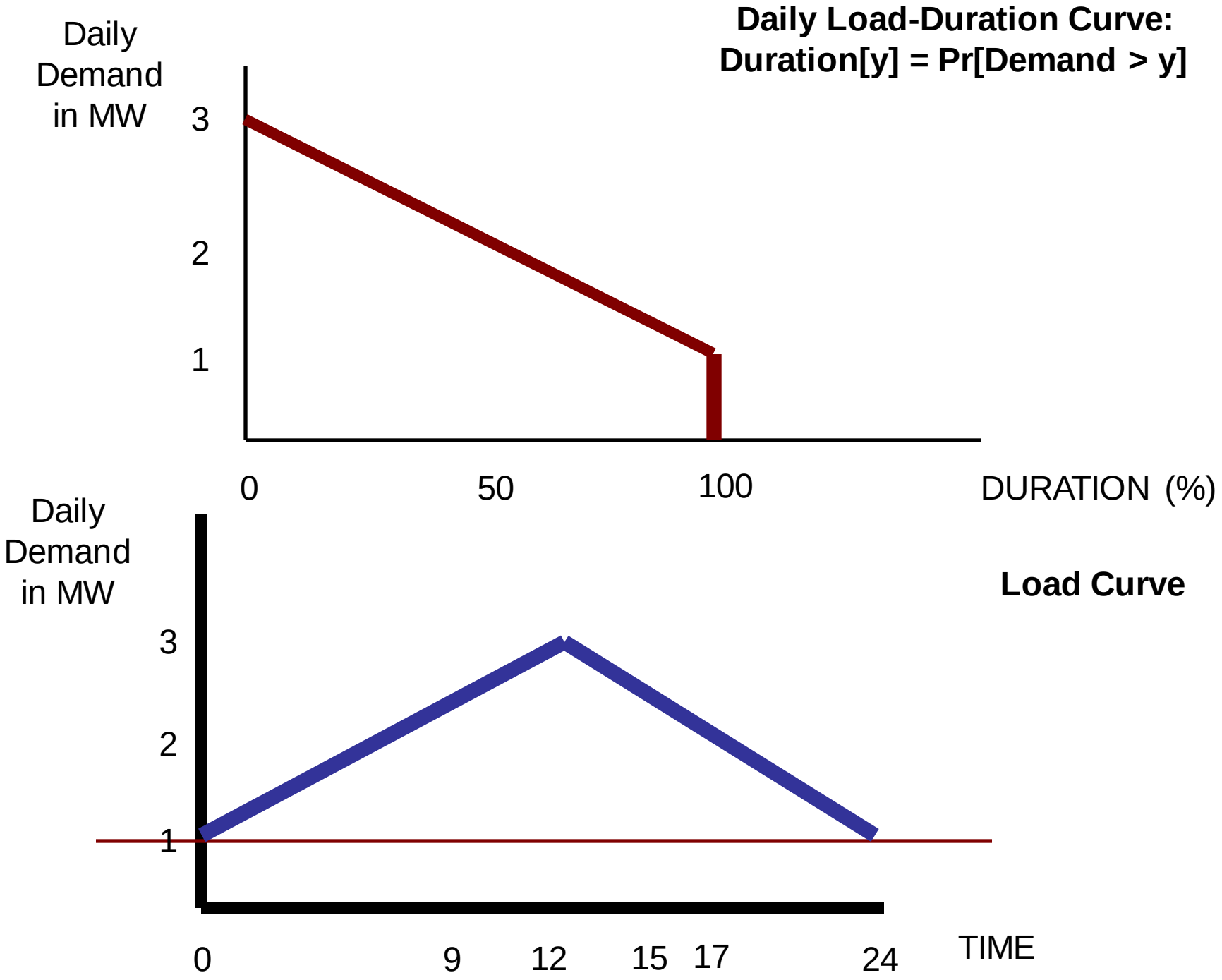
Load Curve

Daily Load-Duration Curve:
Duration[y] = Pr[Demand > y]

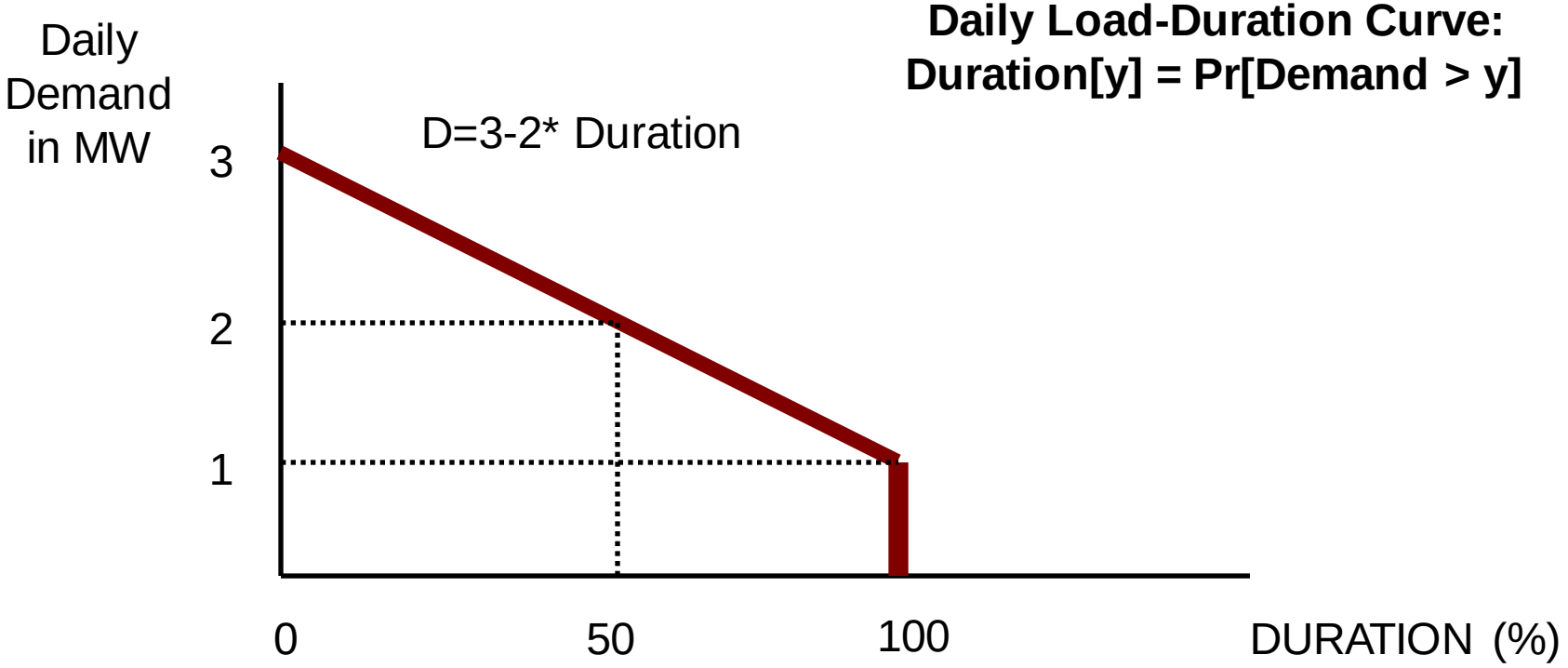


Load Curve



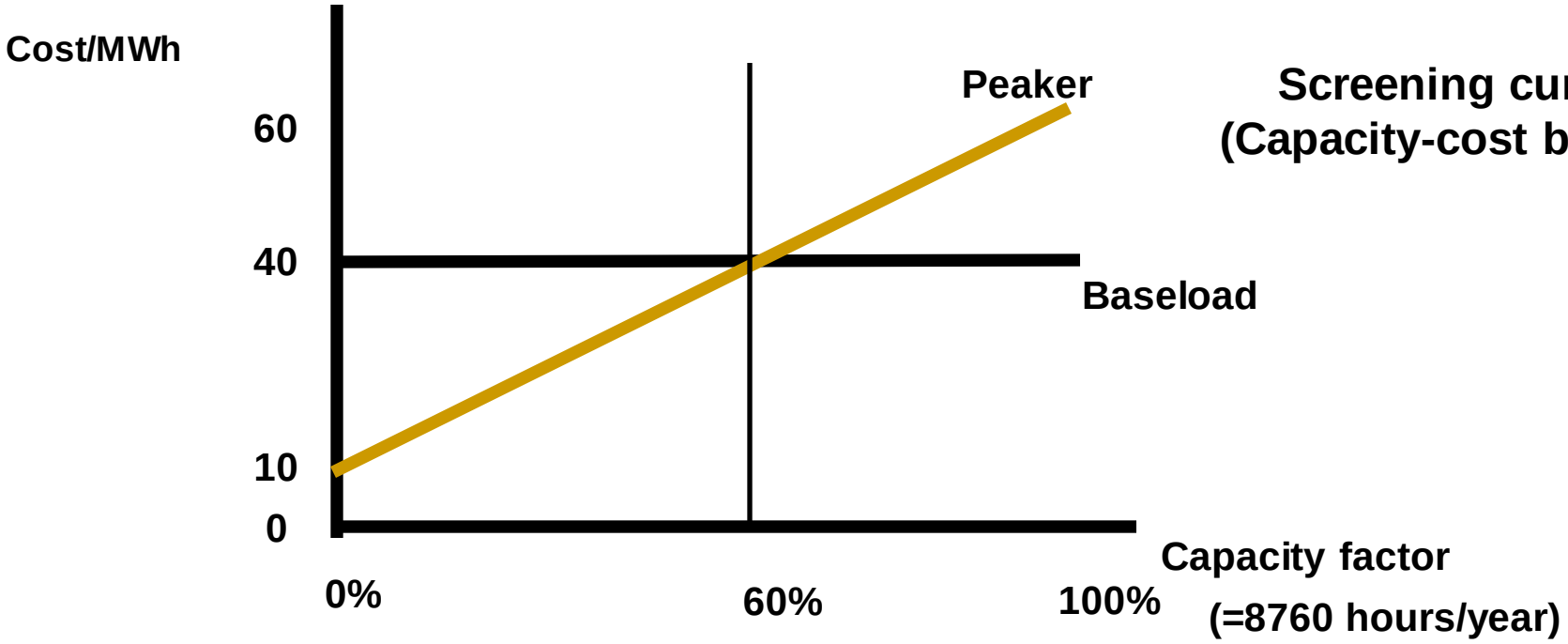

Daily Load-Duration Curve:
Duration[y] = Pr[Demand > y]
Daily
Demand
in MW
3
2
1
0
50
100
DURATION (%)
Daily
Demand
in MW
Load Curve
3
2
1
0
9
12
15
17
24
TIME

Daily Load-Duration Curve:
Duration[y] = Pr[Demand > y]



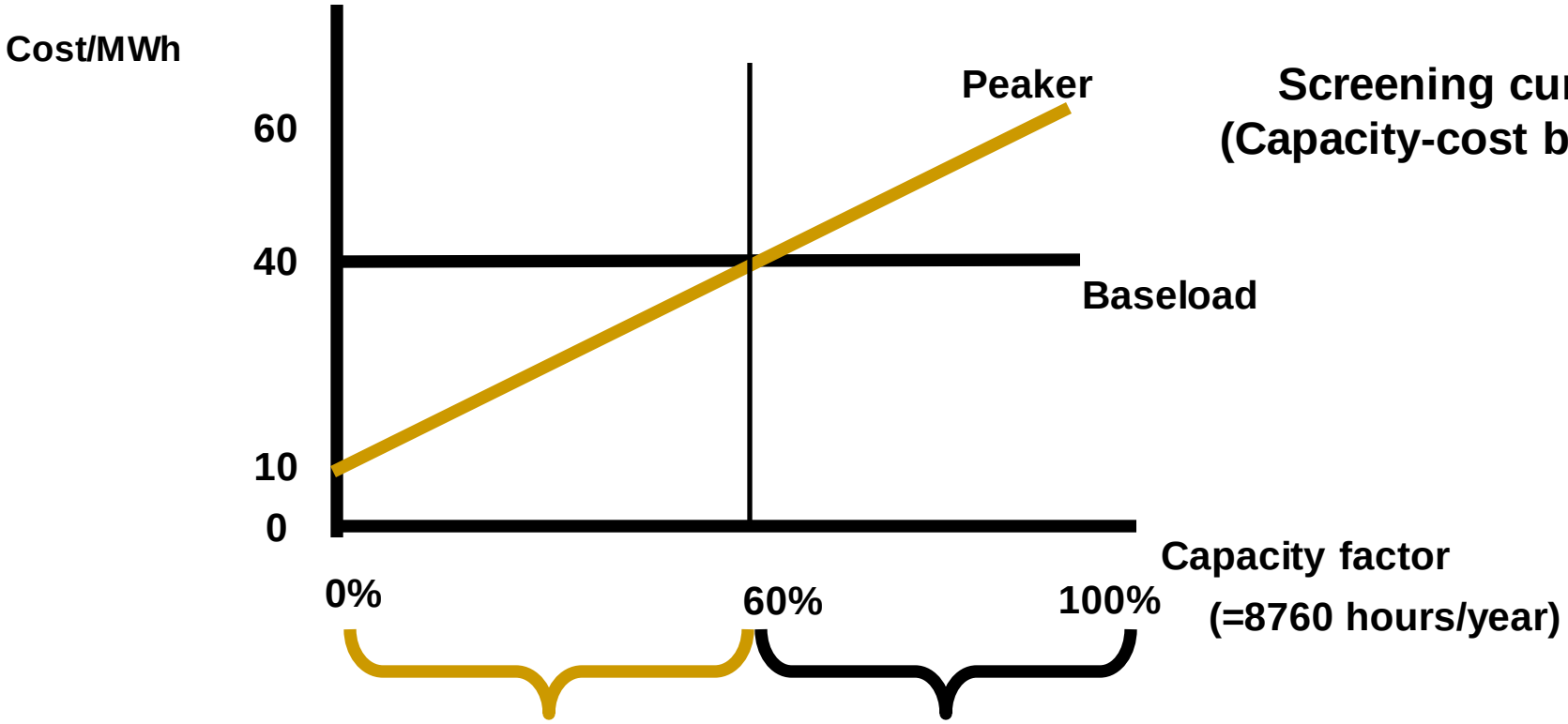
Technology Costs Table

	Fixed cost per MWh	Variable cost per MWh
Baseload	**40**	**0**
Peaker	**10**	**50**



Technology Costs Table

	Fixed cost per MWh	Variable cost per MWh
Baseload	40	0
Peaker	10	50

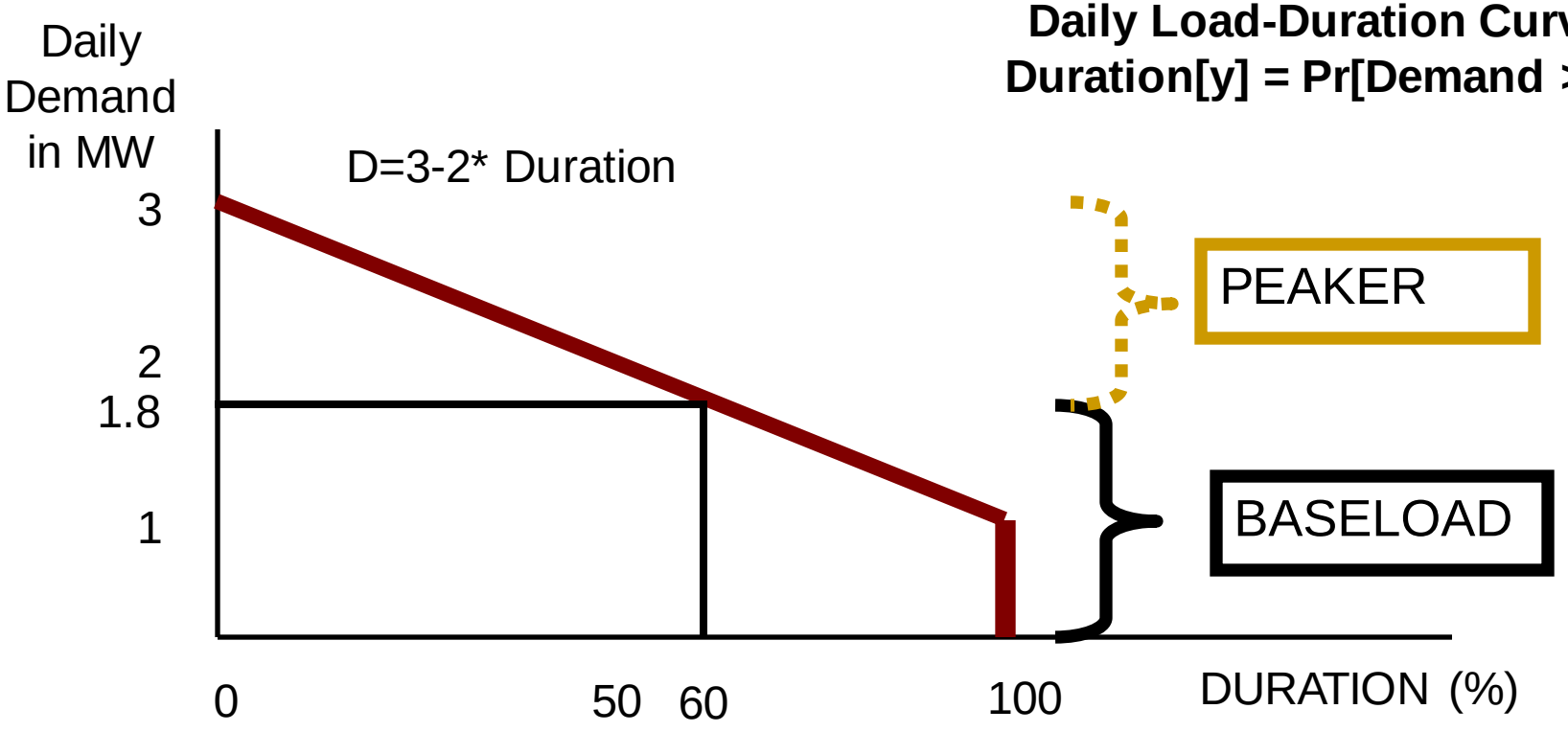


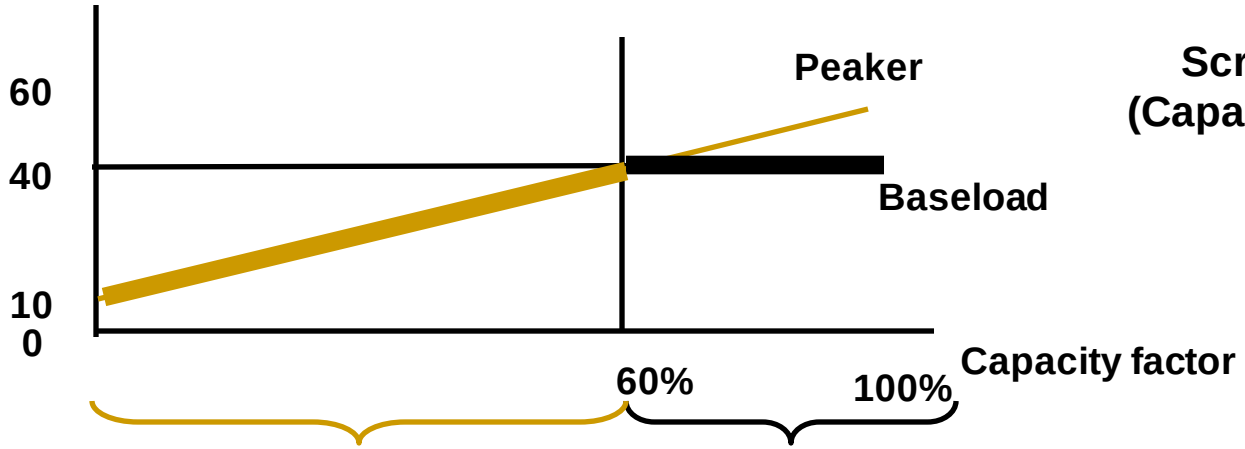
Screening curve (Capacity-cost based)

Technology Costs Table

	Fixed cost per MWh	Variable cost per MWh
Baseload	40	0
Peaker	10	50

Daily Load-Duration Curve:
Duration[y] = Pr[Demand > y]



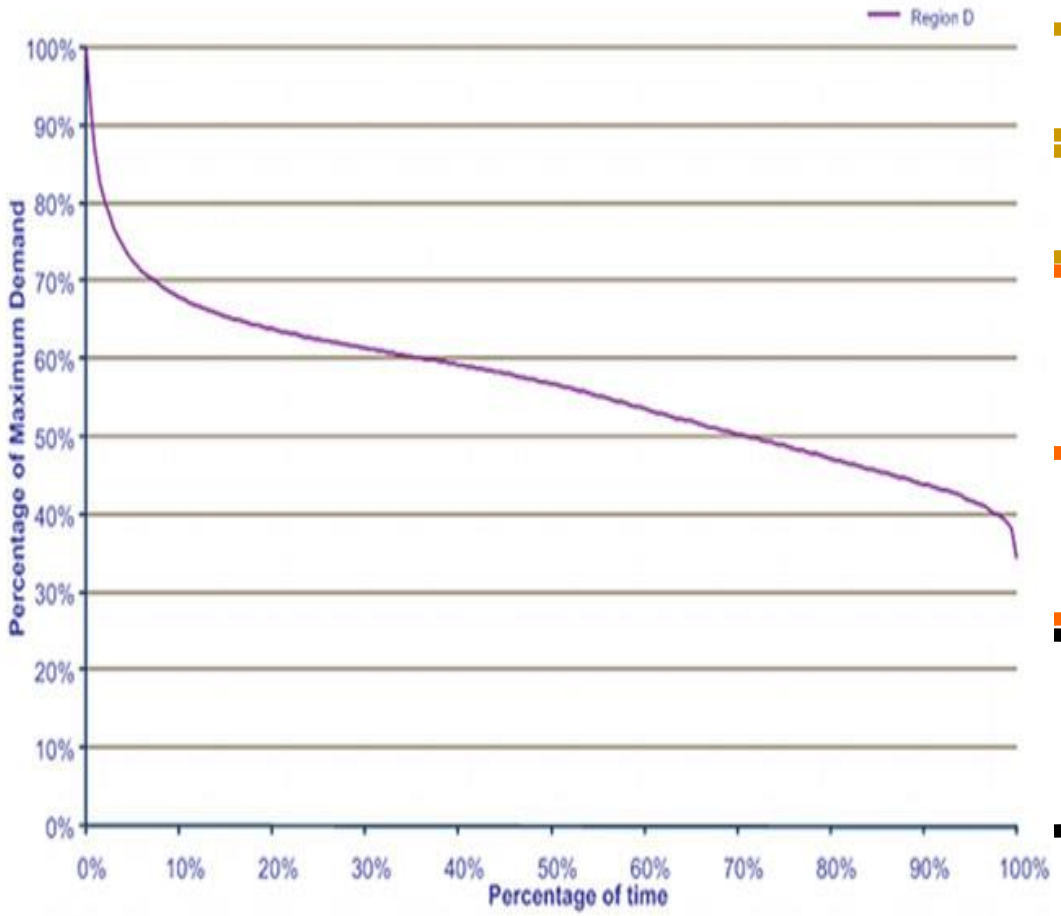


Screening curve
(Capacity-cost based)

Use **peakers** when capacity factor < 60%

Use **baseload** when capacity factor > 60%

Daily Load-Duration Curve:
Duration[y] = Pr[Demand > y]



Oil

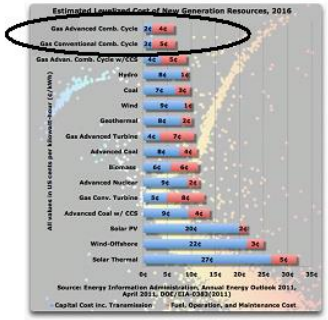
Old, inefficient plants (old Coal & OCGT)

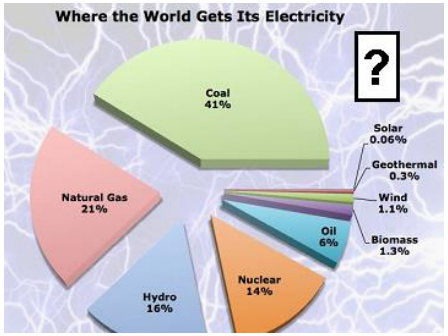
Gas (CCGT)

Coal

Nuclear

1.Why a diversity of generation types?

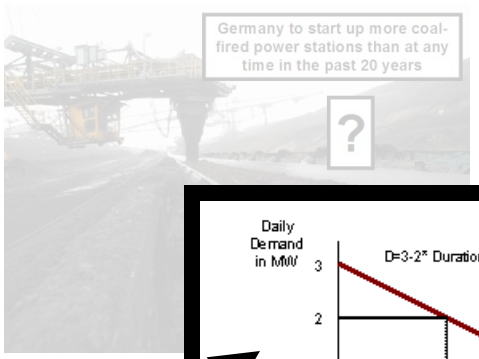


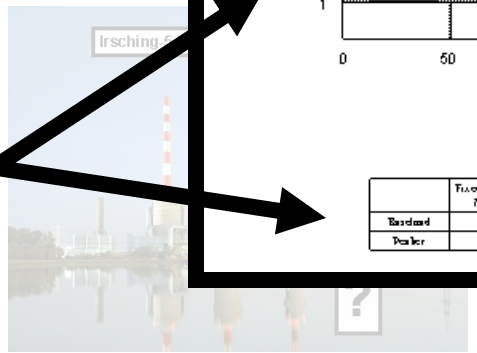


Different fixed & variable cost profiles x

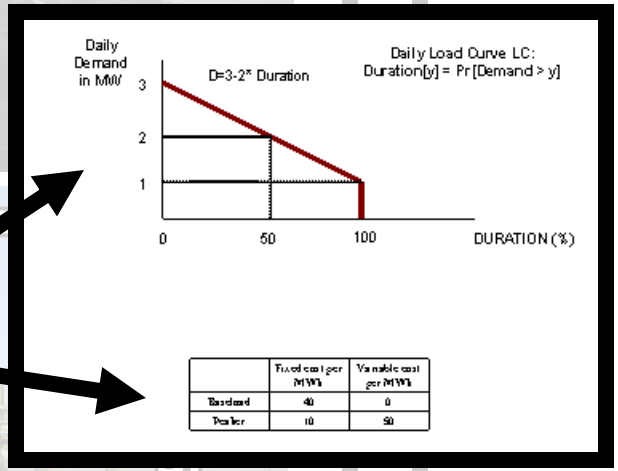
variability in demand

2. Why coal rather than (new) gas generatiors?



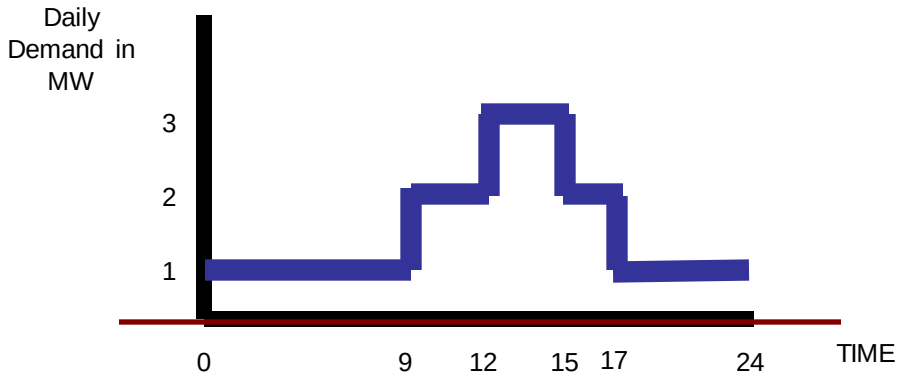


3. Negative prices?

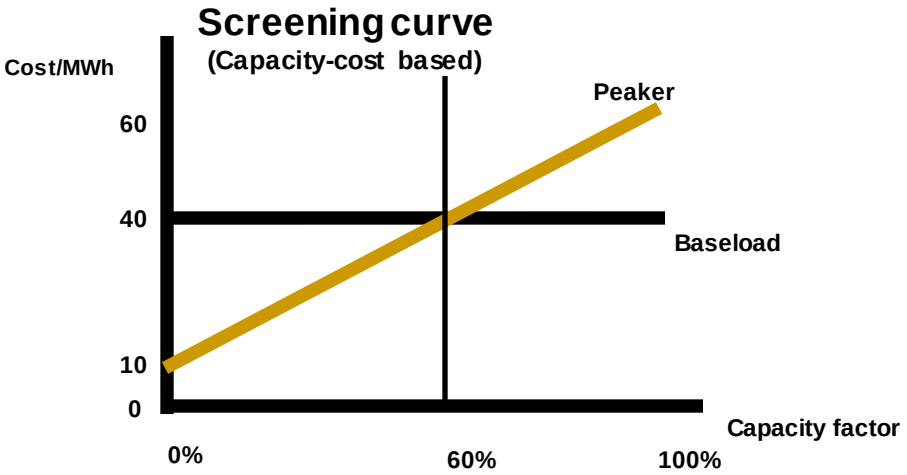


Overview newly introduced curves & table

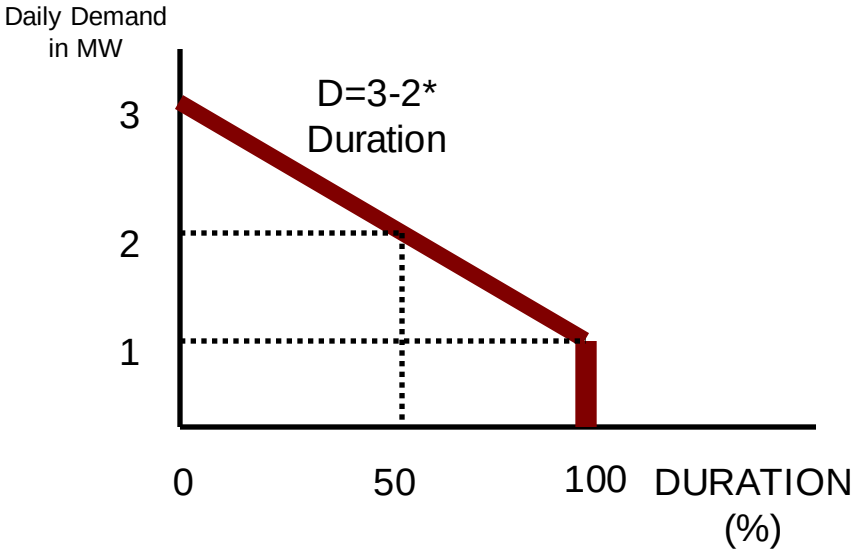
Load Curve



Screening curve



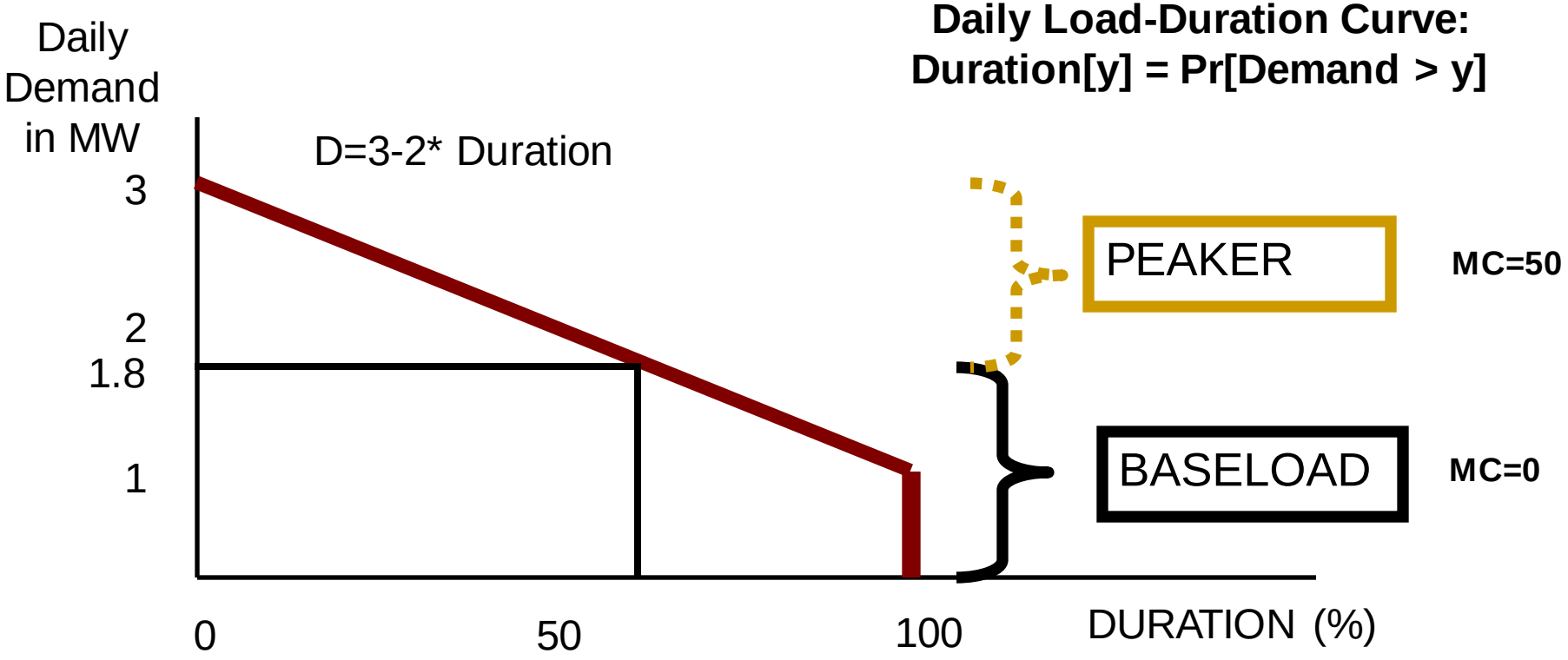
Load-Duration Curve

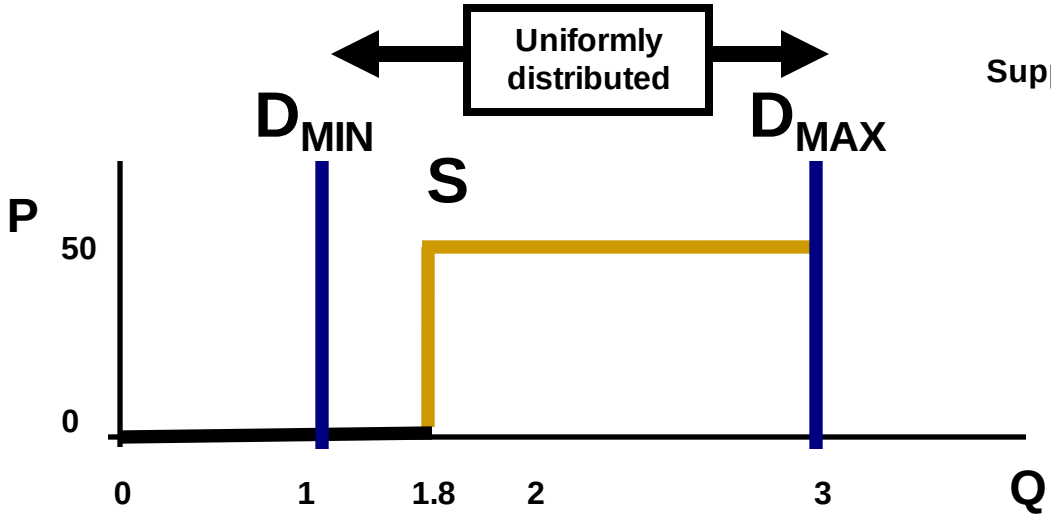


Technology Costs Table

	Fixed cost per MWh	Variable cost per MWh
Baseload	40	0
Peaker	10	50

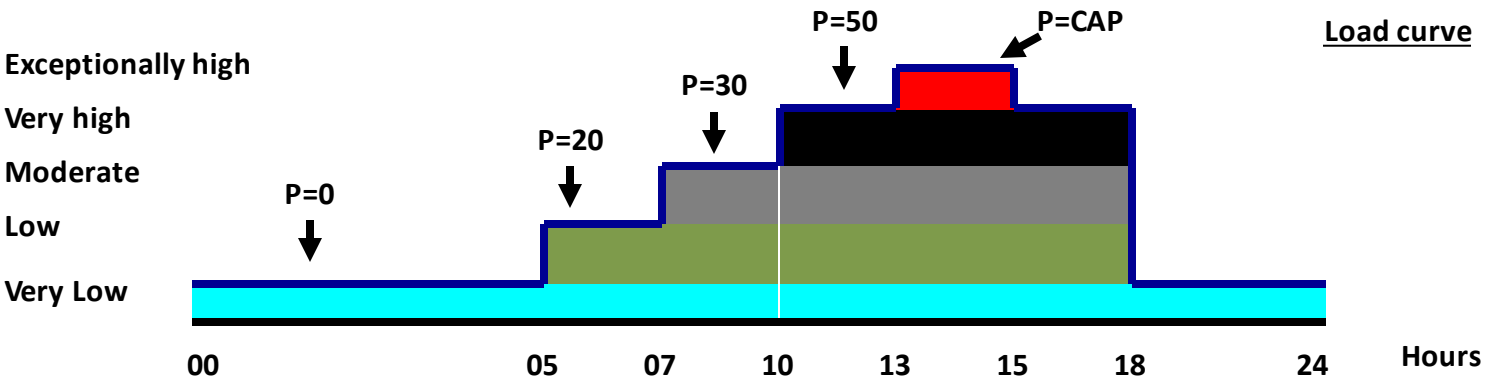
Daily Load-Duration Curve:
Duration[y] = Pr[Demand > y]

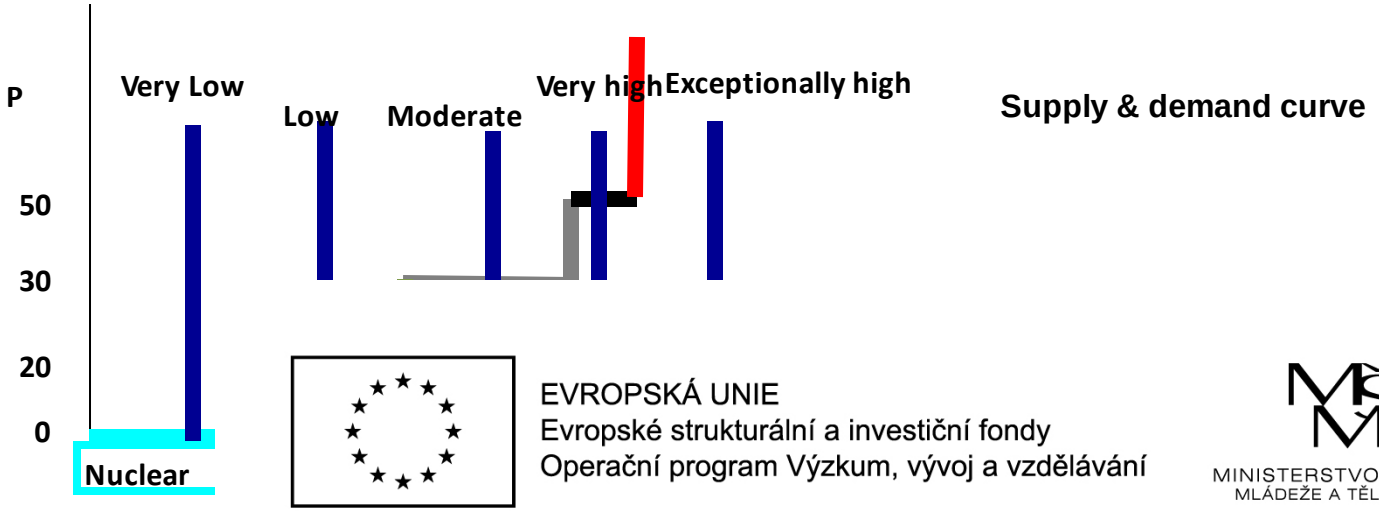




Supply & demand curve

Price is set by the variable costs of the most expensive generator needed to meet demand





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